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LEVEL II

AD A109406

TECHNICAL REPORT
NATICK/TR-81/033

AN INVESTIGATION OF INTEGRATED SIZING FOR US ARMY MEN AND WOMEN

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AUGUST 1981

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: NATICK/TR-81/033	2. GOVT ACCESSION NO.: AD-A109406
	3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): AN INVESTIGATION OF INTEGRATED SIZING FOR U.S. ARMY MEN AND WOMEN	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER: IPL-242
7. AUTHOR(s): John T. McConville, Kathleen M. Robinette, Robert M. White	8. CONTRACT OR GRANT NUMBER(s): DAAK60-79-C-0097
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Anthropology Research Project, Inc., 503 Xenia Avenue, Yellow Springs, Ohio 45387	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62723A, 1L162723AH98-AC-008
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Natick Research & Devel. Laboratories, ATTN: DRDNA-VCAA, Natick, Massachusetts 01760	12. REPORT DATE: August 1981
	13. NUMBER OF PAGES: 67
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Anthropometry	U.S. Army	Field Clothing
Measurement(s)	Military Personnel	Sizing (Clothing)
Body Size	Men	Clothing Design
Sizes (Dimensions)	Women	Size Values

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Described in this report is a step-by-step analysis of anthropometric sizing data leading to the development of integrated sizing programs for use in the design of field clothing for Army men and women.

Spurred by the need to clothe and equip increasing numbers of women for almost all of the Army's occupational specialties, and by the failure of scaled-down men's sizes to properly fit many women, this research was

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undertaken to identify the critical dimensional differences between men and women, and to devise single sizing systems which would take these variations into account.

Concepts underlying the development of anthropometric sizing systems, the problems unique to sizing for a mixed male/female population, and analytic procedures employed in seeking an effective sizing solution are all described here in some detail. Alternative sizing schemes, beginning with those based on traditional key dimensions, are examined and two 20-size programs--one each for upper- and lower-body garments--are recommended.

This report provides the theoretical basis for a proposed sizing system and is designed for persons interested in a general approach which may be applied to the solution of a wide range of integrated sizing problems likely to be encountered by the U.S. Army in providing clothing, equipment and workspaces for both men and women. A companion report (Integrated Size Programs for U.S. Army Men and Women) contains the actual sizing data in a format intended for use by designers and patternmakers.

PREFACE

The research described in this report was conducted by staff members of the Anthropology Research Project (ARP), under the direction of senior investigator John T. McConville. The work was done under contract No. DAAK60-79-C-0097 with the U.S. Army Natick Research and Development Laboratories, Natick, Massachusetts and overseen by Robert M. White, contract monitor.

The authors are grateful to Mr. Charles Clauser and Lt. Colonel Maureen Lofberg of the Workload and Ergonomics Branch, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base for reviewing the manuscript and providing a number of valuable suggestions for its improvement.

The investigation itself would not have been possible without the tireless efforts of ARP's Thomas Churchill in programming and producing the reams of computer data necessary for the analyses. Our appreciation goes, also, to Ilse Tebbetts and Jane Reese of ARP who contributed considerable editorial and typographical expertise in producing this report, and to Stephen H. Horn who was responsible for a number of the graphic presentations.

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Section I

INTRODUCTION

The role of women in the U.S. Army is expanding at a rapid rate both in terms of their increased numbers and as a result of the great increase in the number of occupational specialties for which they are now being trained. These changes require that clothing, personal-protective equipment and workspaces, never before used by Army women, be sized and designed to accommodate their body sizes and physical performance capabilities. Among such items is women's field clothing which is designed for heavy usage and provides the same functional characteristics and degrees of protection for the wearer as are provided for Army men.

The U.S. Army has considered several options for providing identical garments to be worn by both men and women. One such alternative was the design of separate uniforms for women using a sizing system based on measurement data obtained from Army women. While experimental clothing produced by this means performed very well in a fit evaluation (Woodward et al., 1981),[1] the costs of production of two separate sets of field uniforms meeting the same functional needs is less than an optimum solution. Clearly, it would be more desirable to have a single sizing program which accommodates both men and women.

To this end, a second option was considered by the Army, a so-called expanded male system, which entailed modification of an existing male sizing system by the addition of smaller sizes and shorter lengths to accommodate women. This system was based on the common but erroneous assumption that women are scaled-down men; that is, that women are proportionately smaller than men in all dimensions. This assumption has proved to be an invalid one (Robinette et al., 1979).[2] In fact, women are, on the average, larger in some significant dimensions than men so that scaling down certain dimensions only exacerbates the problem. It was not surprising, therefore, that a fit-evaluation of clothing developed in this fashion revealed a poor fit for Army women (Woodward et al., 1981).[1]

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[1]Woodward, Arthur A., Jr., Bernard M. Corona, Maria L. Thomas, and Valeria L. Bachovchin, 1981, Sizing and Fitting Evaluation of Battledress Uniforms for Female Soldiers. Technical Memorandum 7-81, DA Project No. 1G74713L40, Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland.

[2]Robinette, Kathleen, Thomas Churchill and John McConville, 1979, A Comparison of Male and Female Body Sizes and Proportions, AMRL-TR-79-69, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD A074 807)

Although an add-on sizing system is not effective in fitting women, a single sizing system which would eliminate the need to carry an inventory of essentially duplicate items in two size ranges is still being sought. This report documents research leading to the development of an integrated male/female sizing system which incorporates the body size data of persons of both sexes and takes into account the areas of disproportionality between them.

The data analysis was geared to the development of a sizing system for the cotton/nylon twill combat coat and trousers pictured in Figures 1 and 2 (Military Specifications MIL-C-44048 and MIL-T-44047, 1981)[3,4] but the analytic procedures employed are applicable to the development of sizing systems for virtually any items of clothing intended for use by a heterogeneous population of men and women.

Described in the following section are the concepts underlying the development of a sizing system, the problems unique to sizing for a male/female population, and analytic procedures employed to seek an effective sizing solution. A detailed comparison of various alternative programs for upper- and lower-body garments is outlined in Section III. The report concludes with a discussion of analytic results and recommendations in Section IV.

The actual sizing programs which were developed as a result of the analysis are presented in a format usable for designers and pattern-makers in a separate report (Robinette, Churchill and Tebbetts, 1981).[5] While the recommended programs are considered to offer very promising sizing data, they have not yet been subjected to an actual fit evaluation which is the final step in validating the effectiveness of a statistically developed sizing program.

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[3]Military Specification, MIL-C-44048, Coat, Combat, Woodland Camouflage Pattern, 6 August 1981.

[4]Military Specification, MIL-T-44047, Trousers, Combat, Woodland Camouflage Pattern, 5 August 1981.

[5]Robinette, Kathleen M., Thomas Churchill and Ilse Tebbetts, 1981, Integrated Size Programs, for U.S. Army Men and Women, Technical Report, NATICK/TR-81/032, U.S. Army Natick Research and Development Laboratories, Natick, Massachusetts.

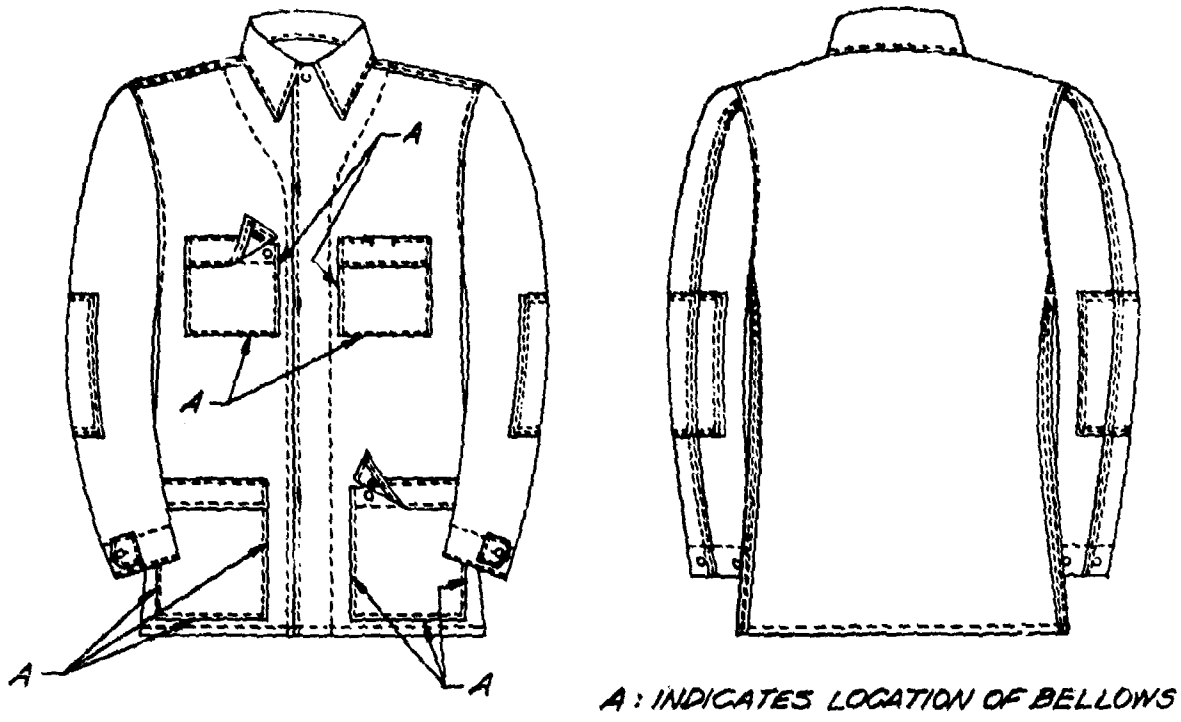

Figure 1. Coat, combat, Woodland Camouflage Pattern.*

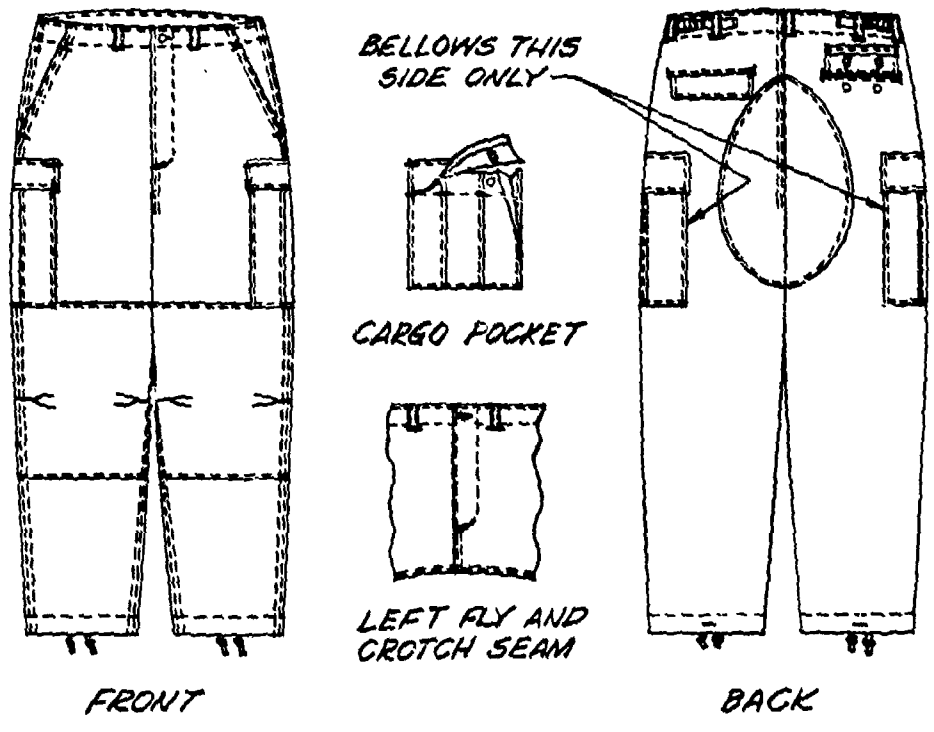

Figure 2. Trousers, combat, Woodland Camouflage Pattern.*

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* Reproduced from MIL-C-44048, 6 August 1981 and MIL-T-44047, 5 August 1981, respectively.

Section II

THE RESEARCH STRATEGY

The concept of creating sizing systems to accommodate a large heterogeneous group of people is based on the assumption that the group, divided into subgroups or sizes of people who are more or less alike for one or two body size dimensions, will also be similar in all other dimensions important in the construction of a garment. For example, if stature and weight are considered the best dimensions for sorting the subgroups, and persons between 5'2" and 5'4" in stature and between 120 and 140 pounds in weight comprised one of the groups, then the sizing assumption is that almost all persons in that group can be accommodated for sleeve length, hip circumference, and other dimensions because they would be similar in those measurements as well. When attempting to create a sizing system integrating both men and women, this assumption must be carefully examined.

The Problem

In a previous study (Robinette, Churchill and McConville, 1979),[6] a group of men and women of comparable age were matched one-to-one for stature and weight and their other dimensions were then compared (see Table 1). Despite the fact that the average stature and weight differences were less than 0.01 inch and 0.1 pound, respectively, the average differences between some of the other dimensions were quite large. The two most mismatched dimensions were hip circumference and shoulder circumference, both important in sizing. For hip circumference, the women were larger, on the average, by 2.29 inches, and for shoulder circumference the men were larger, on the average, by 2.62 inches.

These variations provide an explanation for the results of a recent fit-evaluation of the clothing developed for Army women by merely expanding a male sizing program downwards (Woodward et al., 1981).[7] As previously noted, this sizing program attempted to accommodate women by adding smaller sizes to a sizing system based on male body proportions and used for the design of men's clothing. The fitting problems which surfaced during the test, according to the report, "resulted almost exclusively from the inherent incompatibility between male clothing patterns and the body proportions of women, particularly in the region of the hips and of the shoulders." Specifically, the male-sized coats could not be fitted satisfactorily on women's shoulders if they were large enough to fit over the hips, and if the male-sized pants were large enough for women in the hips, they were too large in the waist and entirely too long.

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[6]See reference 2.

[7]See reference 1.

TABLE 1

DIFFERENCES BETWEEN MEN AND WOMEN
OF EQUAL* STATURE AND WEIGHT
U.S. ARMY 1977 (n=204)

Variable	Mean Diff**	SD
Weight	0.10	1.00
Stature	0.01	0.13
Axilla Height	+0.53	0.78
Chest Height	0.03	1.06
Waist Height	+2.16	1.39
Buttock Height	+0.47	1.53
Shldr-Elbow Lgth	0.09	0.62
Elbow-Fingertip Lgth	0.51	0.91
Chest Depth	+0.76	0.66
Waist Depth	0.44	0.71
Shoulder Circ	2.62	1.51
Chest Circ	0.59	1.74
Waist Circ	1.58	2.01
Hip Circ	+2.29	1.46
Biceps Circ, Flx	1.32	0.71
Calf Circ	+0.39	0.71
Ankle Circ	+0.01	0.48
Interscye, Back	0.73	1.23
Interscye, Front	0.79	0.74
Back Curve-Chest	0.65	0.94
Back Curve-Waist	0.69	1.17
Back Curve-Hip	+1.27	1.15
Waist Back Lgth	0.69	1.38
Waist Front Lgth	1.12	1.27
Sleeve Inseam Lgth	+0.09	1.06
Sleeve Outseam L	0.33	1.05

* Matched to within ± 0.5 inches and 2.6 pounds.
** Positive value indicates female is larger.

In order to develop a successful integrated program, these differences between male and female body proportions must be accommodated. With this in mind, we began the development of several alternative sizing programs in an attempt to determine if a solution was possible and, if so, to determine if one program represented a significant improvement over another.

Development of an Anthropometric Sizing Program

The sequence of steps involved in the development of any anthropometric sizing system is as follows: (1) selection of an appropriate body of data for analysis, (2) selection of the key or sizing dimensions, (3) selection of intervals for the key dimensions that will establish the limits of each size category, (4) development of the dimensional data for each of the established size categories, and (5) establishment of design values.

While the selection of the body of data for analysis (Step 1) is usually a relatively straightforward matter, the second step, the choice of key sizing dimensions, is of crucial importance but is seldom, if ever, clear-cut. By key dimensions, we mean those measurements by which the people will be sorted and by which the garment will actually be sized. Commercially, for example, men's trouser sizes are often based on waist circumference and inseam length and are sometimes, though not always, so labelled.

The key dimensions should be conveniently measurable and have a high degree of correlation with other dimensions which are of importance in the design and sizing of the end items. That is, in the case of men's trousers, changes in the waist circumference size will reflect corresponding changes in other girths, such as hip circumference, while changes in inseam length will correspond with changes in other linear dimensions, such as waist height. In short, the key dimensions must exert enough "control" over other dimensions so that persons who are bigger or smaller in the key dimensions will be correspondingly bigger or smaller in the other relevant dimensions as well.

Step 3 calls for the establishment of size intervals. That is: how wide a range of body sizes will have to be accommodated by each clothing size? The selection of size category intervals is greatly facilitated by the use of a bivariate frequency plot which shows the subject population distributed on a grid defined by the key sizing dimensions. Figure 3 illustrates such a bivariate devised for the sizing of upper body garments for Army women (Robinette, Churchill and McConville, 1981).[8] Each box

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[8]Robinette, Kathleen M., Thomas Churchill and John T. McConville, 1981, Anthropometric Sizing Systems for Army Women's Field Clothing, Technical Report, NATICK/TR-81/026, U.S. Army Natick Research and Development Laboratories, Natick, Massachusetts. (AD A102 104)

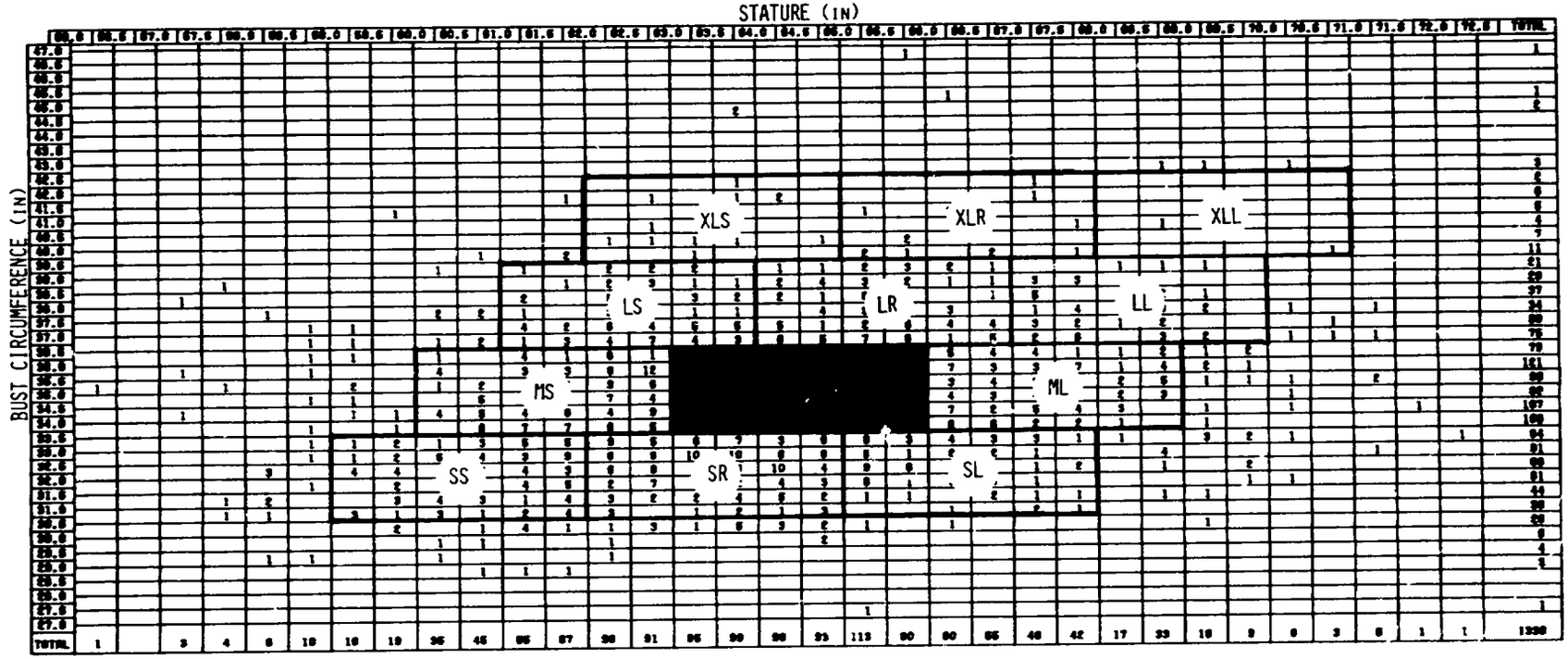

Figure 3. A bivariate frequency plot with 12 size categories superimposed.*

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* SS = Small Short
SR = Small Regular
SL = Small Long
MS = Medium Short
MR = Medium Regular
ML = Medium Long
LS = Large Short
LR = Large Regular
LL = Large Long
XLS = Extra-Large Short
XLR = Extra-Large Regular
XLL = Extra-Large Long

represents a given stature and bust circumference measurement (designated at the top and left of the bivariate, respectively) and numbers in each box reflect the number of women of that particular stature and bust circumference combination to be found in the sample population. Superimposed on the bivariate is a 12-size program based on those two measurements. As can be seen, each size encompasses a three-inch range of stature and a three-inch range of bust circumference. Thus, for example, the women who are between 63 and 66 inches tall and have bust circumferences between 33.5 and 36.5 inches fall in the size category designated Medium Regular (shaded in Figure 3).

Since the width of the size interval of the key dimensions dictates the number of sizes which will be required, it is not only the body size variability that must be considered but factors such as the type of fit required, the material that will be used in fabrication, the cut, and possibly the logistics of procurement and stockage of the final item. The major thrust of any such decision, of course, is to provide the best fit possible for the maximum number of users with the fewest number of sizes. Inevitably, there will be individuals within the design group who, because of extremes in body dimensions or unusual proportions, will not be satisfactorily fitted. An effective sizing scheme, however, will keep the number of individuals unaccommodated to a minimum. A count of subjects located outside the sizing boxes in Figure 3, for example, reveals 8% unaccommodated. Some proportion of these will actually be able to wear sizes represented by adjacent boxes and one could safely estimate that the pictured size program will probably accommodate about 95% of the user population.

Step 4 is development of the dimensional data; that is, determination of sleeve lengths, neck circumferences, and all the other relevant dimensions of the individuals within each size category. While this step is a purely computational procedure, a careful study of its results is essential to the assessment of the program. It is these data which are the test of the original assumption on which all successful sizing programs are based: namely, that carefully selected key dimensions will control all other dimensions sufficiently to produce homogeneous groups of measurements within each size category.

Dimensional data are calculated in terms of a range of values; thus, for example, computing arm circumference at scye for all the women in the Medium Regular size category of the 12-size upper body program pictured in Figure 3, resulted in a "range to be accommodated" of 13.82 inches to 15.91 inches. The designer or patternmaker, of course, requires a single value in the actual fabrication of a garment and step 5 consists of computations from which final recommended design values are obtained for each dimension in each size program. Since it is axiomatic that smaller persons can, if necessary, wear larger garments but larger persons cannot be accommodated by too-small garments, upper key dimension values are usually selected as input for the calculations used to obtain final recommended design numbers. (See Appendix A for details on how design values are computed.)

The Statistics of Sizing

Dimensional data are arrived at by treating all the individuals in the sample who fall within the limits of each size category as a subsample and computing summary statistics for each of the dimensions to be included in the program. (Of course, the dimensions selected for the size program must have been measured on the subjects in the sample.)

The statistical method most commonly used to describe the range of values in a given group of normally distributed data involves establishment of a mean value to which multiples of standard deviations are added and subtracted. Figure 4 is a graph of the theoretical "normal" distribution and illustrates the magnitude of the range covered by various multiples of the standard deviation (SD).

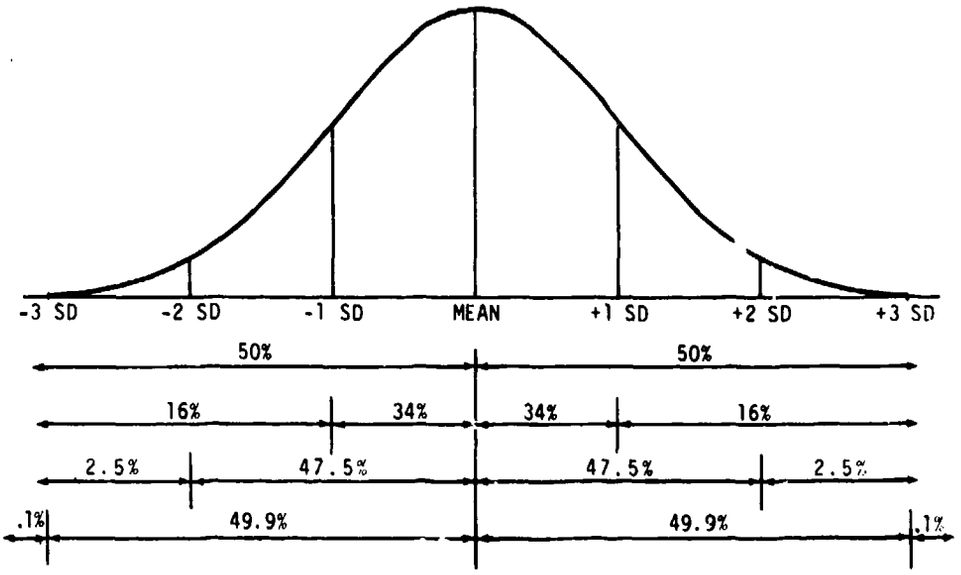

Figure 4. Normal distribution indicating approximate population percentiles with specified standard deviations (SD).

For sizing purposes, however, this approach must be somewhat modified since dimensional data divided into size categories are not normally distributed and tend to cluster toward the mean of the total sample. (This can be verified by a study of the distribution of subjects of a sizing bivariate such as that pictured in Figure 3.) The within-a-size mean values also tend to be skewed toward the total population mean. To correct this problem, so-called "mid-size values" are computed from multiple regression equations using size category midpoints as predictors.* The effect of this procedure

* Procedures for computing all the sizing data presented in this report are described in Appendix A.

is to even the distribution throughout each size category and to avoid penalizing subjects in the least populated areas of each category.

A modified "standard deviation" called the within-a-size standard deviation (SZ-SD) is also computed and is applied with the mid-size value just as a standard deviation is applied to a mean. Thus, the mid-size value plus or minus 1.65 SZ-SD's should encompass approximately 90% of the persons within a given size, just as the mean value plus or minus 1.65 SD's does for the total sample. A combination of the mid-size value and the SZ-SD, then, enables designers to determine how small and how large to expect persons to be for a particular dimension within a particular size and establishes the adjustability which will be necessary to accommodate most persons within that size. These values are termed the "range to be accommodated" and specify the range of variation for each body dimension to be accommodated in a size program.

Thus, the dimensional data for each size consists of a mid-size value (equivalent to a mean), a within-a-size standard deviation or SZ-SD (equivalent to a standard deviation) and a "range to be accommodated" for each dimension. Added to these statistics on a sizing table are the recommended design values for each dimension. A typical sizing table, excerpted from a 12-size program for upper body garments for Army women (Robinette, Churchill and McConville, 1981),[9] is illustrated in Table 2.

An Approach to Integrated Sizing

In seeking to develop a sizing system usable by both sexes, we employed the traditional steps described above with significant modifications mandated by the need to take into account the proportional differences between men and women.

Subjects used in the sizing analysis were drawn from the 1966 Army male survey (White and Churchill, 1971)[10] and the 1977 Army female survey (Churchill et al., 1977).[11] Table 3 compares summary statistics for the two samples. The men are, on the average, taller (plus 4.56 inches) and heavier (plus 26.99 pounds) than the women, and larger for all body dimensions listed, on the average, than women except for the dimensions of hip breadth and hip circumference where the women are larger.

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[9]Ibid.

[10]White, Robert M. and Edmund Churchill, 1971, The Body Size of Soldiers, U.S. Army Anthropometry - 1966, Technical Report 72-51-CE, U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 743 465)

[11]Churchill, Edmund, Thomas Churchill, John T. McConville and Robert M. White, 1977, Anthropometry of Women in the U.S. Army--1977; Report No. 2 - The Basic Univariate Statistics, Technical Report NATICK/TR-77/024, U.S. Army Natick Research and Development Command, Natick, Massachusetts (AD A044 806)

TABLE 2

12-SIZE PROGRAM FOR THE UPPER BODY*
MEDIUM REGULAR

The Range for Bust Circumference 33.50 - 36.49
The Range for Stature 63.00 - 65.99

N = 286 Tariff Percentage = 23.91%

Variable	Mid-Size Value	SZ-SD	Range to be Accommodated	Recommended Value
Weight	134.56	10.27	117.61-151.51	146.69
HEIGHTS				
Axilla Height	48.81	0.90	47.33-50.30	50.06
Bustpoint Height	46.84	1.04	45.12-48.56	48.00
Buttock Height	33.20	1.15	31.31-35.09	34.12
Cervicale Height	55.93	0.91	54.43-57.43	57.33
Crotch Height	30.26	1.01	28.59-31.92	31.08
Shoulder Height	52.87	0.95	51.30-54.44	54.28
Stature	64.50	0.87	63.07-65.93	66.00
Waist Height	40.16	1.10	38.34-41.97	41.19
LENGTHS				
Acromion - Axilla	4.06	0.35	3.48- 4.64	4.21
Axilla to Waist	9.13	0.95	7.56-10.70	9.30
Cervicale-Acromion	3.06	0.30	2.57- 3.55	3.05
Cerv - Bustpoint	9.09	0.74	7.86-10.32	9.33
Cervicale - Buttock	22.73	1.05	21.00-24.47	23.21
Neck to Bustpoint	10.02	0.65	8.95-11.10	10.38
Sleeve Inseam	17.84	0.73	16.63-19.04	18.26
Sleeve Outseam	21.30	0.79	20.00-22.61	21.84
Shoulder to Elbow	13.29	0.44	12.56-14.03	13.64
Waist Back	16.16	0.91	14.66-17.66	16.49
Waist Front	14.53	0.93	13.00-16.07	14.89

* Units are inches or pounds.

TABLE 2 (continued)

12-SIZE UPPER BODY
MEDIUM REGULAR

Variable	Mid-Size Value	SZ-SD	Range to be Accommodated	Recommended Value
CIRCUMFERENCES				
Arm Circ at Scye	14.87	0.63	13.82-15.91	15.38
Biceps Circ, Flxd	10.65	0.66	9.57-11.74	11.05
Bust Circumference	35.00	0.87	33.57-36.43	36.50
Bust-Waist, Circ	6.81	1.63	4.12- 9.51	7.01
Chest Circ at Scye	33.89	1.12	32.05-35.73	35.02
Chest C Below Bust	29.65	1.13	27.79-31.52	30.72
Elbow Circ, Flxd	10.29	0.52	9.43-11.14	10.58
Forearm Circ, Flxd	9.75	0.47	8.98-10.52	10.03
Hip Circumference	37.86	1.74	34.99-40.74	39.20
Neck Circumference	12.79	0.50	11.96-13.62	13.07
Shoulder Circ	39.74	1.30	37.59-41.89	40.92
Vertical Trunk Circ	60.92	1.81	57.94-63.91	62.65
Waist Circ	28.19	1.78	25.25-31.13	29.49
Wrist Circ	5.81	0.22	5.45- 6.18	5.94
ARCS				
Back Arc, Bust	16.64	0.74	15.41-17.86	17.27
Back Arc, Hip	18.83	1.15	16.93-20.72	19.49
Back Arc, Waist	14.01	0.92	12.49-15.53	14.65
Interscye Back	14.97	0.81	13.63-16.31	15.30
Interscye Front	13.12	0.57	12.17-14.06	13.41
Shoulder Length	5.93	0.39	5.28- 6.57	6.02
DEPTHS AND BREADTHS				
Bust Depth	9.10	0.46	8.34- 9.87	9.56
Chest Breadth	11.19	0.42	10.50-11.89	11.58
Hip Breadth	14.01	0.76	12 75-15.27	14.47
Shoulder Breadth	16.64	0.57	15.70-17.59	17.12
Waist Breadth	10.15	0.70	9.00-11.30	10.60
Waist Depth	7.26	0.62	6.24- 8.28	7.62

TABLE 3

COMPARISON OF SUMMARY STATISTICS*
(Values are inches and pounds)

Variable	1966 ARMY MEN (n=6682) Mean	SD	1977 ARMY WOMEN (n=1330) Mean	SD	Mean Diff	SD
Weight	159.10	23.35	132.11	18.76	26.99	4.59
HEIGHTS AND LENGTHS						
Shoulder-Elbow Lgth	14.52	0.73	13.21	0.69	1.31	0.04
Shoulder Height	56.58	2.45	52.55	2.36	4.03	0.09
Sleeve Inseam	19.13	1.05	17.74	1.03	1.39	0.02
Stature	68.71	2.60	64.15	2.57	4.56	0.03
Waist Back Lgth	17.73	1.35	16.08	1.04	1.65	0.31
Waist Height	41.86	2.11	39.92	2.05	1.94	0.06
ARCS AND BREADTHS						
Chest Breadth	12.04	0.84	11.12	0.72	0.92	0.06
Hip Breadth	13.07	0.79	13.92	0.96	+0.85	+0.17
Interscye Back	15.39	1.24	14.90	0.92	0.49	0.32
Shoulder Brdth	17.86	1.00	16.55	0.87	1.31	0.13
Shoulder Lgth	6.38	0.78	5.90	0.42	0.48	0.36
CIRCUMFERENCES						
Arm Circ at Scye	17.54	1.28	14.77	0.94	2.77	0.34
Bust/Chest Circ	36.92	2.63	34.72	2.49	2.20	0.14
Hip Circ	37.09	2.46	37.59	2.48	+0.50	+0.02
Neck Circ	14.72	0.81	12.74	0.62	1.98	0.19
Shoulder Circ	44.55	2.51	39.51	2.11	5.04	0.40
Vertical Trunk Circ	64.61	3.34	60.56	2.84	4.05	0.50
Waist Circ	31.61	3.22	27.94	2.67	3.67	0.55
Wrist Circ	6.72	0.34	5.79	0.27	0.93	0.07

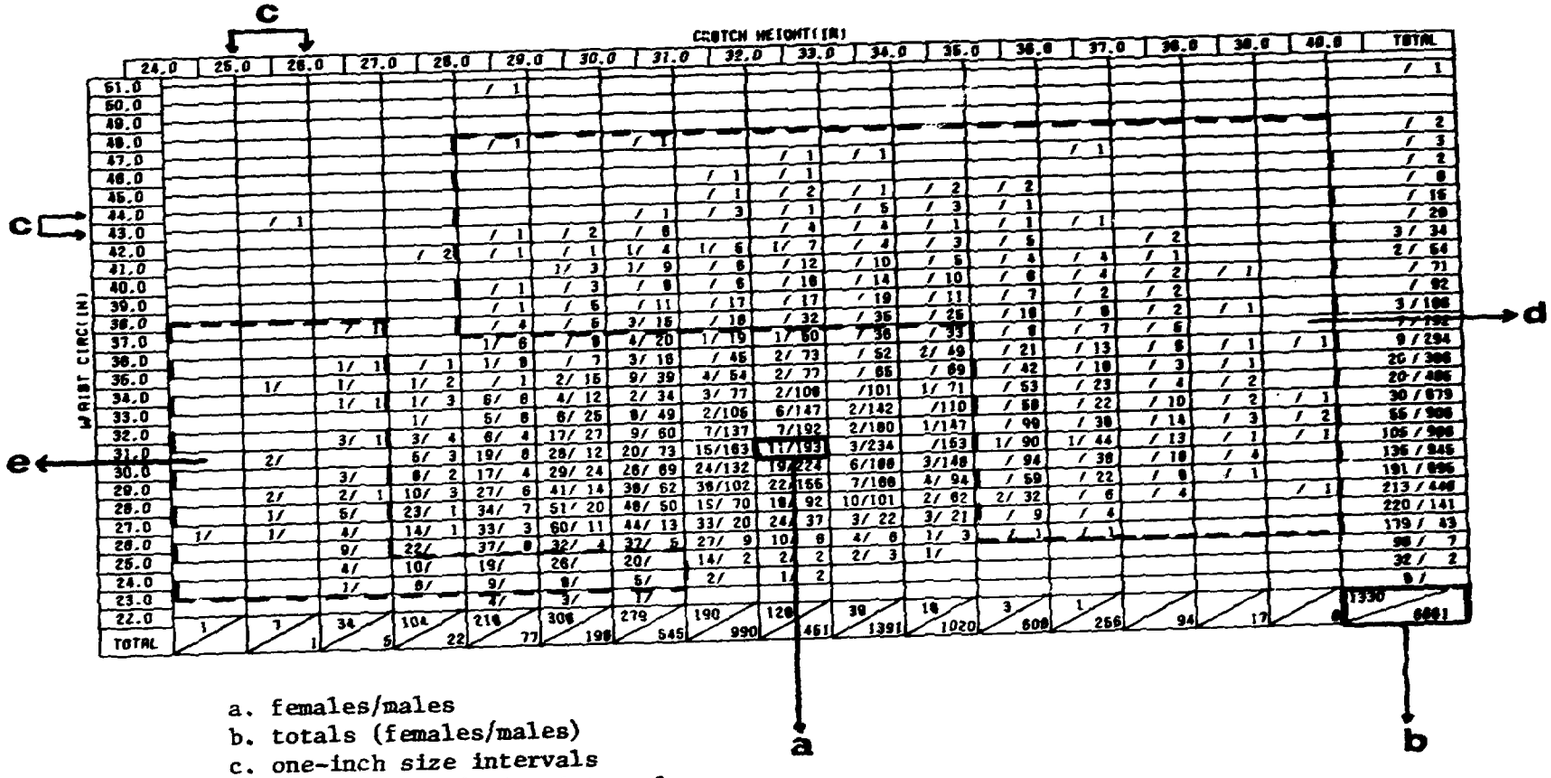
* A positive sign (+) indicates the females are larger.

The unique problems presented by the range of variability in the dimensions of the two samples, as well as the areas of disproportionality between the two sexes, suggested that a unique approach was needed to amalgamate the two samples in a unified sizing system.

The most obvious way to combine samples would be simply to throw them together, calculating within-a-size means, SZ-SD's, "ranges to be accommodated" and design values from the mix of men and women to be found in each sizing category. The practical drawbacks of this method, however, are legion. Design values would be based on the particular percentages of males and females to be found in Army populations of the past whereas the Army of the future may well recruit a much higher percentage of women than is currently the case By the same token, since there are more than five times as many men in the total sample as there are women, values within a given sizing category would be unduly weighted to favor men. Furthermore, indiscriminate mixing of male and female values can produce anonymous averages which represent neither men nor women and compromise both.

We chose, instead, to maintain identifiably separate values for both sexes throughout the sizing analysis. This will enable the designer, among other things, to design for men alone or women alone in those size categories which overwhelmingly contain only men or women. The advantage of this can be illustrated by the so-called double bivariate depicted in Figure 5. This bivariate shows the distribution of both men and women for crotch height and waist circumference, two candidate key dimensions for lower body garments. Numbers of female subjects in each bivariate cell appear to the left of the slash, males to the right (a). The sums by row and column are given at the bottom and right of the table (b). The intervals of the two variables (one inch) are designated as the start and end point for each bivariate cell (c). As can be seen, if size categories were superimposed on the top and right-hand portions of the bivariate, they would take in chiefly only men (d), while to a lesser extent some of the smaller sizes would encompass only female values (e). Thus, maintenance of discrete male and female values will allow us to recommend design values based strictly (and more accurately) on men's or women's data for those sizes where it is appropriate and to integrate the data in those central portions of any sizing program where both men and women exist.

In those areas of integration, too, men's and women's dimensional data were kept separate so each could be given equal consideration. Integrated sizes were arrived at by overlapping the "range to be accommodated" values of each sex to determine the combined range necessary to accommodate 90% or more of <u>all</u> persons in each category. Figure 6 illustrates the overlapping of separately documented male and female values for the purpose of arriving at a combined "range to be accommodated." Ankle circumference values in inches are indicated across the top. The range width for females in this size for ankle circumference was 1.5 inches, ranging from 7.6 inches to 9.1 inches. The male "range to be accommodated" began at 7.9 inches and went to 9.5 inches making the range width 1.6 inches. The "combined" range extends from the smallest of the two, in this case the female at 7.6 inches, to the largest, in this case the male at 9.5 inches, creating a range width of 1.9 inches.



a. females/males
b. totals (females/males)
c. one-inch size intervals
d. male-dominated size intervals
e. female-dominated size intervals

Figure 5. A bivariate frequency table for crotch height and waist circumference (1977 Army women/1966 Army men).

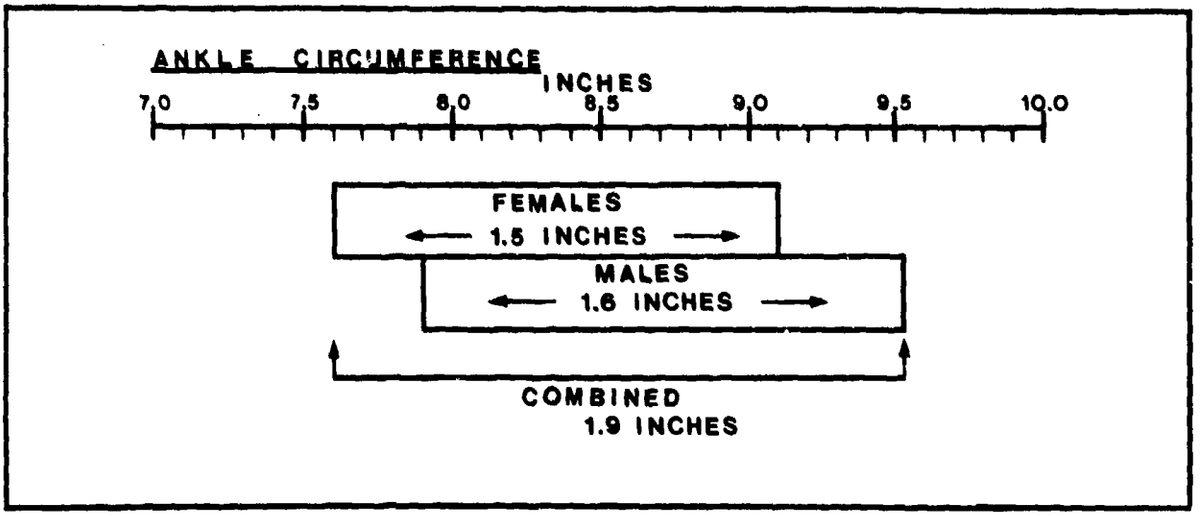


Figure 6. Ankle circumference separate and combined ranges for Medium Regular of a 20-size waist circumference and crotch height program.

In summary, the method of analysis used to arrive at an integrated male/female sizing system was to initially establish sizing programs for males and females separately, using the same key dimensions and size intervals, and to compare the resulting range of values to be accommodated. The optimum integrated size system would then be devised from that combination of key dimensions and size intervals which would reduce the combined range of accommodation of critical body dimensions to a minimum. In Section III we begin with a discussion of the upper body sizing program analysis and follow with a parallel discussion of the lower body sizing program analysis.

Section III

COMPARISON OF ALTERNATIVE INTEGRATED PROGRAMS

Upper Body

The first pair of key sizing dimensions selected for analysis were those used for sizing the combat coat described in MIL-C-44048,[12] namely, chest circumference and stature. That document describes a male sizing program containing 19 size categories of varying chest circumference and stature interval widths, with open-ended intervals at the small and large ends (see Figure 7).

The female dimensions initially paired with these male dimensions were the traditional ones, bust circumference and stature. In the following discussion, integrated sizing programs which use these key dimensions will be called bust/chest circumference and stature programs.

Stature has a good correlation with other linear dimensions, and both chest and bust circumferences have good correlations with other dimensions related to mass, particularly on the upper body. This makes stature and chest or bust circumference effective key dimensions for separate male and female programs.

After a comparative analysis of three bust/chest circumference and stature programs using different interval widths and numbers of sizes (15, 20 and 25 sizes), we selected a 20-size program which is shown outlined on the bivariate in Figure 8. The 20-size program was selected as it offered a significant reduction in the within-size standard deviation over the 15-size program and was essentially equal to the within-size variance of the 25-size program. This program has consistent bust/chest circumference interval widths of three inches and stature interval widths of four inches for all sizes in the program. Although in this regard it differs from the uneven sizing categories used in the sizing program for the male combat coat described above, it can be seen that the evenly distributed 20-size program covers the distribution of both men and women reasonably well, encompassing 99% of the male sample and 94.8% of the female sample.

Next, the dimensional data were computed for each size for each sex and the separate "range to be accommodated" values were compared to determine the combined range. The separate and combined ranges for size Medium Regular (the category outlined darkly in Figure 8) are presented in tabular form in Table 4.

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[12] See reference 3.

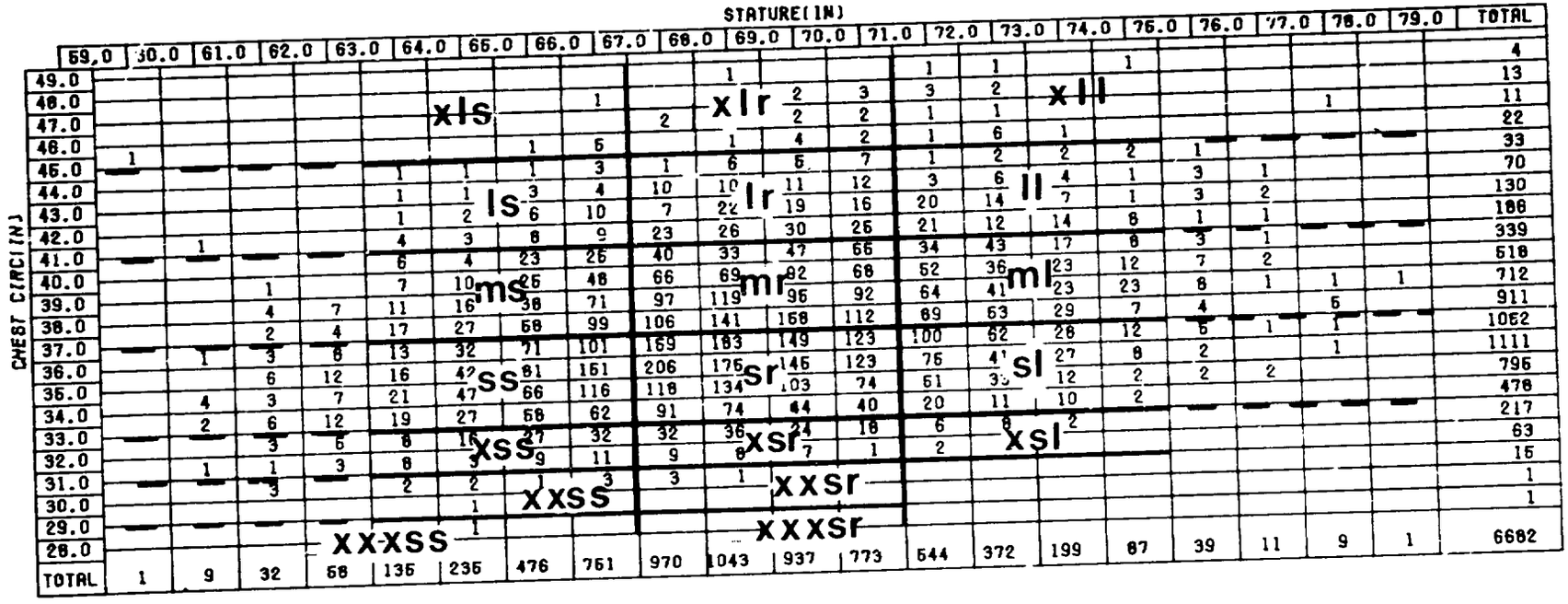

Figure 7. An illustration of size categories used for combat coat from Military Specification, MIL-C-44048, Coat, Combat, Woodland Camouflage Pattern, 6 August 1981, superimposed on Army male distribution.

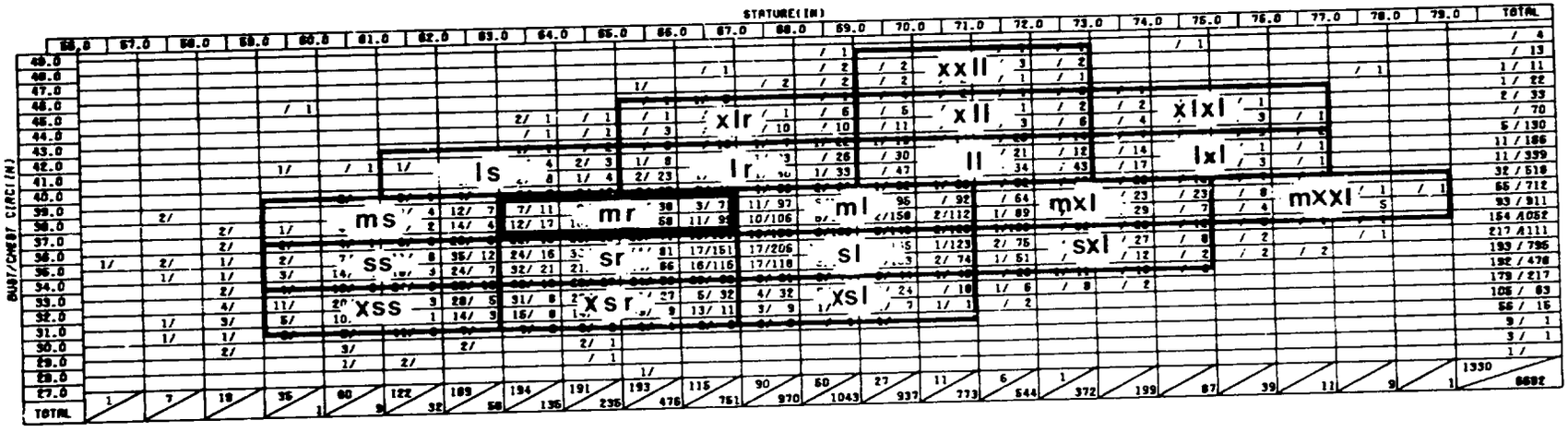

Figure 8. An illustration of size categories for a 20-size stature and bust/chest circumference program (1977 Army women/1966 Army men).

TABLE 4

20-SIZE BUST/CHEST CIRCUMFERENCE AND STATURE PROGRAM*
SIZE MEDIUM REGULAR

The Range for Bust/Chest Circumference 36.5-39.49
The Range for Stature 63.0-66.99

	RANGE TO BE ACCOMMODATED					
	Male	Width	Female	Width	Combined	Combined Width
Weight	135.0-177.9	(42.9)	134.9-169.4	(34.5)	134.9-177.9	43.0
HEIGHTS & LENGTHS						
Shoulder-Elbow L	12.9-14.7	(1.8)	12.7-14.2	(1.5)	12.7-14.7	2.0
Shoulder Height	51.3-55.4	(4.1)	51.6-55.4	(3.8)	51.3-55.4	4.1
Sleeve Inseam	16.7-19.3	(2.6)	16.6-19.2	(2.6)	16.6-19.3	2.7
Stature	63.1-66.9	(3.8)	63.1-66.9	(3.8)	63.1-66.9	3.8
Waist Back Lth	15.0-19.1	(4.1)	14.8-17.8	(3.0)	14.8-19.1	4.3
Waist Height	37.0-41.6	(4.6)	38.4-42.4	(4.0)	37.0-42.4	5.4
ARCS & BREADTHS						
Chest Breadth	11.3-13.1	(1.8)	11.2-12.6	(1.4)	11.2-13.1	1.9
Hip Breadth	12.0-13.9	(1.9)	13.4-15.9	(2.5)	12.0-15.9	3.9
Interscye Back	13.9-17.3	(3.4)	14.1-16.8	(2.7)	13.9-17.3	3.4
Shoulder Breadth	16.9-19.1	(2.2)	16.5-18.4	(1.9)	16.5-19.1	2.6
Shoulder Length	5.0- 7.5	(2.5)	5.3- 6.6	(1.3)	5.0- 7.5	2.5
CIRCUMFERENCES						
Arm Circ at Scye	16.0-19.3	(3.3)	14.7-16.8	(2.1)	14.7-19.3	4.6
Bust/Chest Circ	36.6-39.4	(2.8)	36.6-39.4	(2.8)	36.6-39.4	2.8
Hip Circ	34.7-39.9	(5.2)	37.0-42.8	(5.8)	34.7-42.8	8.1
Neck Circ	13.8-15.9	(2.1)	12.4-14.0	(1.6)	12.4-15.9	3.5
Shoulder Circ	42.7-47.5	(4.8)	39.7-44.0	(4.3)	39.7-47.5	7.8
Vert Trunk Circ	59.3-67.3	(8.0)	59.8-66.0	(6.2)	59.3-67.3	8.0
Waist Circ	29.1-36.0	(6.9)	27.8-33.7	(5.9)	27.8-36.0	8.2
Wrist Circ	6.1- 7.1	(1.0)	5.6- 6.3	(0.7)	5.6- 7.1	1.5

* Units are inches or pounds.

Also shown in Table 4 are the "combined widths"--that is, the width of the range to be accommodated from the smallest to the greatest values of either sex. In some instances, the combined widths are no larger than the separate male or female ranges (shoulder height, interscye, vertical trunk circumference, etc.). In other instances, the combined range is considerably wider (hip breadth, arm scye, hip circumference, shoulder circumference, waist circumference). The combined range width of hip circumference (8.1 inches) is some 156% of the male range (5.2 inches), and for shoulder circumference (7.8 inches) some 163% of the male range width (4.8 inches). Figures 9 and 10 were prepared to illustrate the separate male and female ranges to be accommodated, as well as the combined ranges, for the hip circumference and shoulder circumference dimensions within this size (Medium Regular).

It is the increase in the combined range width for dimensions in critical fitting areas which will determine whether or not an integrated program will work, and it should be clear from Figures 9 and 10 that within this size the increase resulting from combining men and women appears unacceptably large for these two dimensions. In practice, it would mean that garments of a single size would have to be designed to accommodate persons whose hip circumferences might vary by so much as 8.1 inches, and whose shoulder circumference measurements might vary by almost that much. This, of course, represents only one of 20 sizes. To get a clearer picture of the situation, all sizes containing both men and women were studied. To this end, we summarized the information by averaging the combined range widths for all the sizes. The combined averages are presented in Table 5, along with separate male and female average range widths, and the percentages of separate range widths which are represented by the combined widths.

The percentage values in this table give an indication of what might be termed the "cost of accommodation." The percentage value indicates how large the combined variance width will be with respect to each separate variance width (on the average) in this program. For example, to effectively accommodate the males for sleeve inseam within a size, a range of 2.63 inches will need to be considered. By adding women, the combined range only increases 2% beyond the male range. The value 102% means 100% of the male plus 2% more to accommodate women also. By the same token, it is clear that by adding women to men, the variance to be accommodated for hip breadth more than doubles (211%). That is, the average range width of male hip breadths to be accommodated in any sizing system is 1.86 inches, and when females are added to the population to be accommodated, the average range width grows to 3.93 inches.

To graphically illustrate these points, we prepared Figure 11 which, in addition to depicting the relationships in a more visual manner, shows where the ranges fall with respect to each other. For sleeve-inseam length, for example, the female range falls at the bottom of the combined range while the male falls at the top and the cost of accommodation is 102% of the male range due to the broad overlap of the male and female values. For hip circumference, the reverse is true. For this variable, there is relatively little overlap of the male and female ranges with females at the top of the

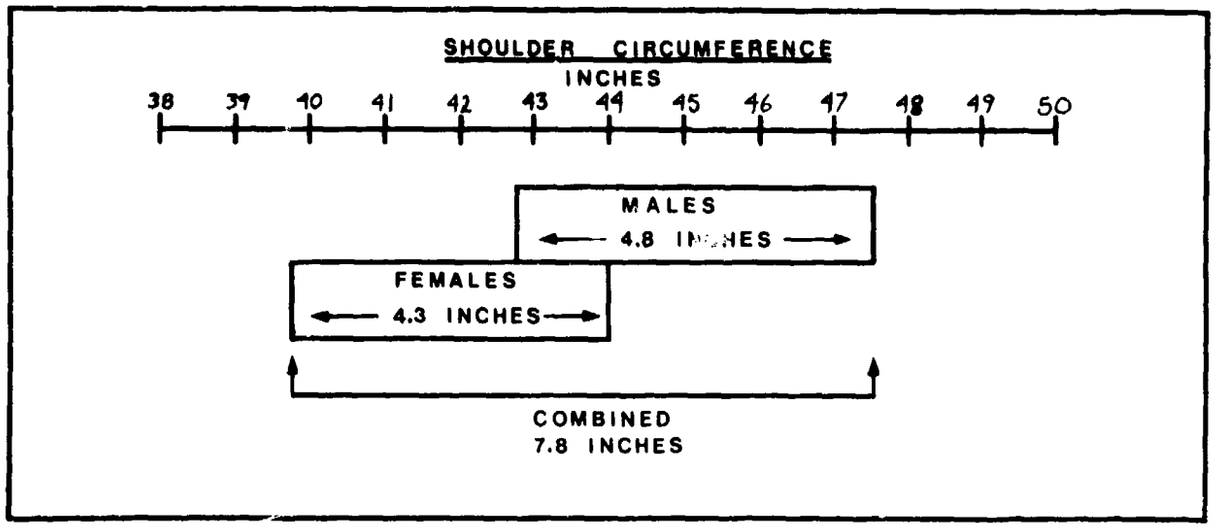

Figure 9. Comparison of shoulder circumference ranges, size Medium Regular, 20-size program.

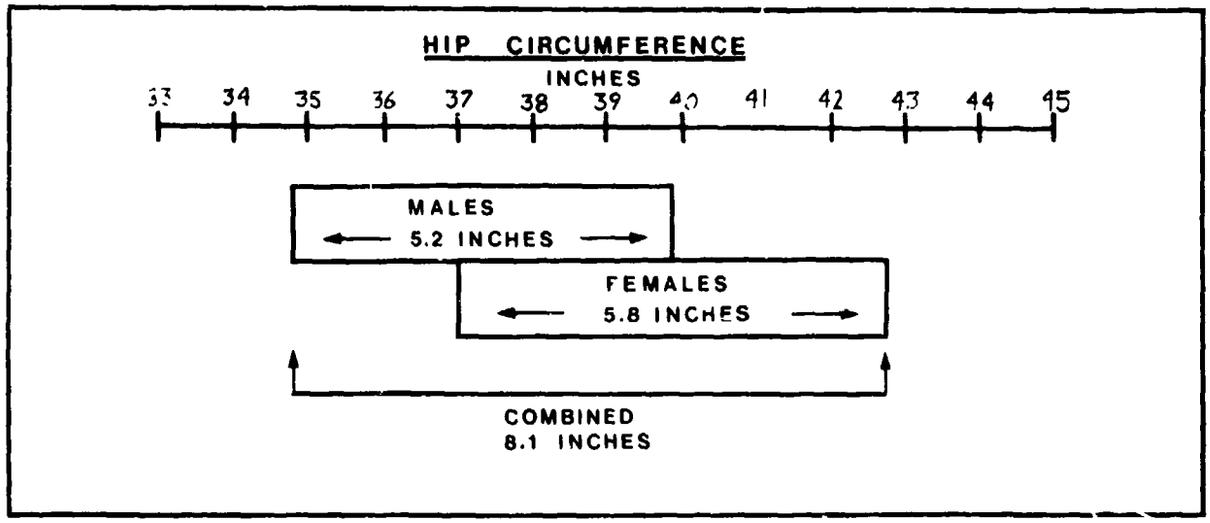

Figure 10. Comparison of hip circumference ranges, size Medium Regular, 20-size program.

TABLE 5

AVERAGE RANGE WIDTHS
FOR THE 20-SIZE BUST/CHEST CIRCUMFERENCE AND STATURE PROGRAM*

Variable	Average Range Widths			Combined Percentages of	
	Male	Female	Combined	Male	Female
Weight	42.90	34.55	44.98	105	130
HEIGHTS AND LENGTHS					
Shoulder-Elbow Lgth	1.79	1.56	2.00	112	128
Shoulder Height	4.16	3.84	4.16	100	108
Sleeve Inseam	2.63	2.53	2.68	102	106
Stature	3.82	3.82	3.82	100	100
Waist Back Length	4.07	3.04	4.30	106	141
Waist Height	4.60	4.06	5.53	120	136
ARCS AND BREADTHS					
Chest Breadth	1.73	1.39	1.85	107	133
Hip Breadth	1.86	2.53	3.93	211	155
Interscye Back	3.40	2.69	3.50	103	130
Shoulder Breadth	2.18	1.90	2.53	116	133
Shoulder Lgth	2.53	1.30	2.53	100	195
CIRCUMFERENCES					
Arm Circ at Scye	3.25	2.10	4.58	141	218
Bust/Chest Circ	2.86	2.86	2.86	100	100
Hip Circ	5.18	5.79	8.33	161	144
Neck Circ	2.17	1.67	3.46	159	207
Shoulder Circ	4.83	4.30	7.72	160	180
Vert Trunk Circ	8.03	6.16	8.03	100	130
Waist Circ	6.94	5.89	8.18	118	139
Wrist Circ	0.95	0.73	1.50	158	205

* Units are inches or pounds.

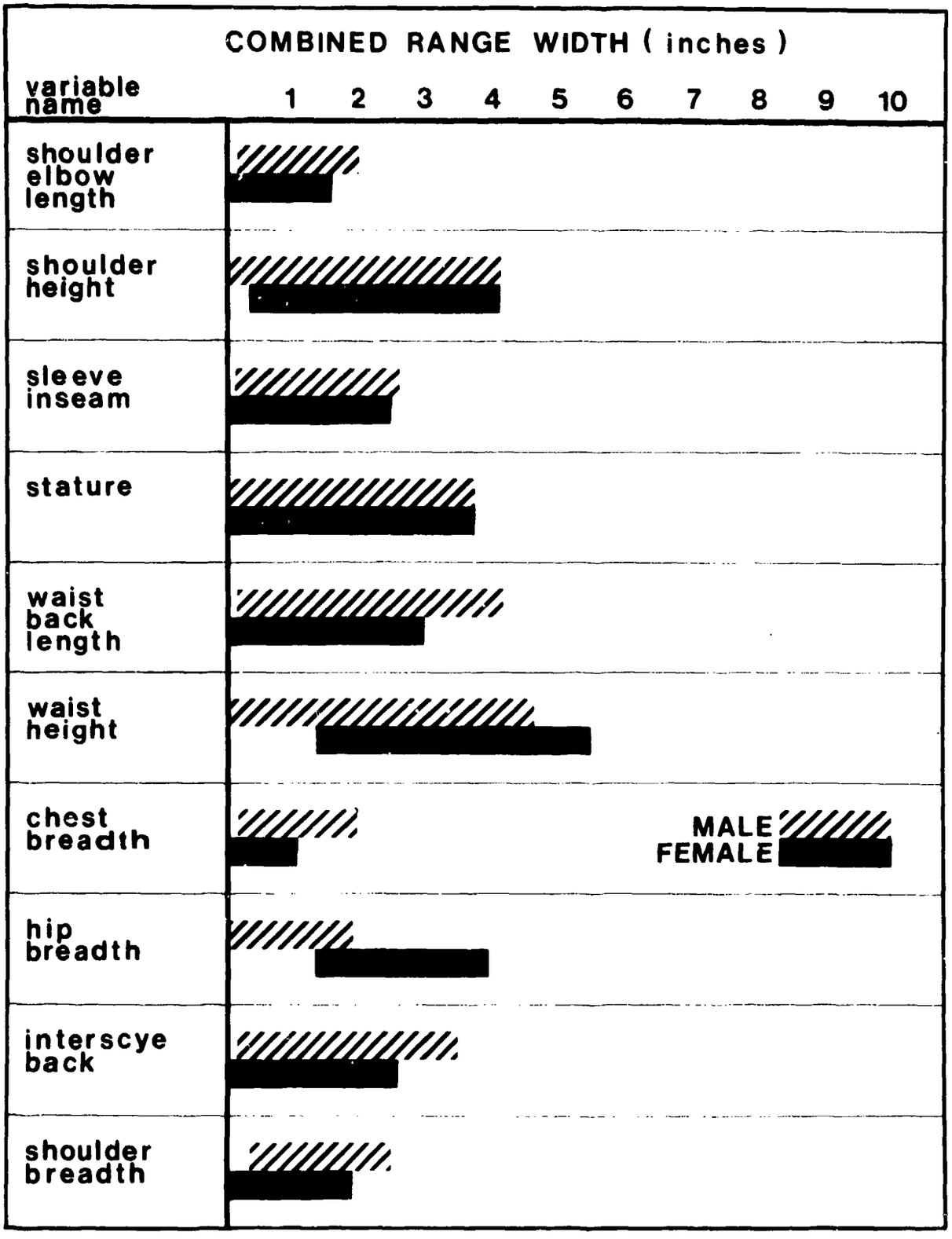

Figure 11. Comparison of average range widths, 20-size bust/chest circumference and stature program.

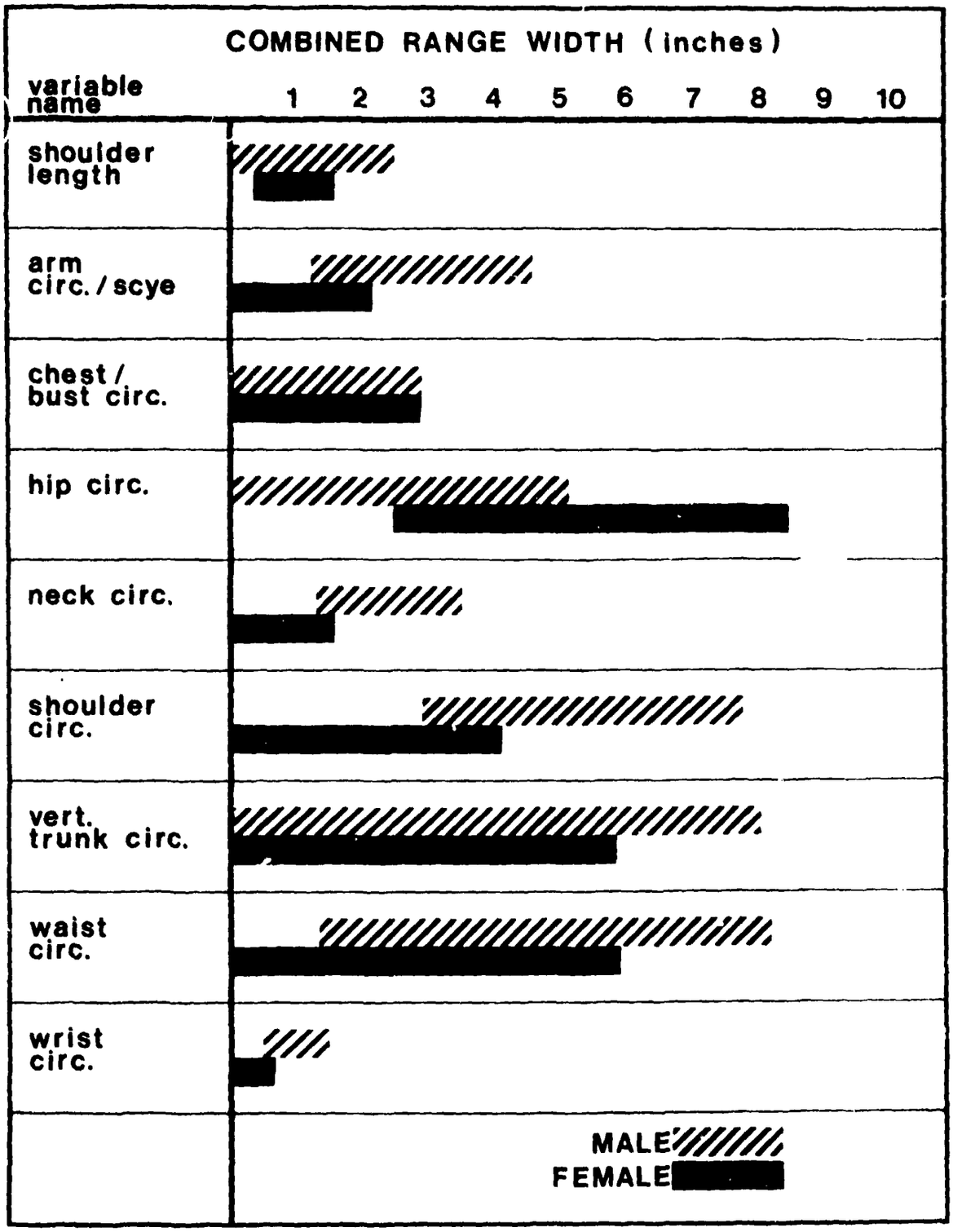

Figure 11. (cont'd)

combined ranges. As a consequence, the combined cost of accommodation is 161% of the male range. For the dimension shoulder circumference, the male range is at the top of the combined range with a small area of overlap and the cost of accommodation for the combined range is 160% of the male range--this time, in the opposite direction.

As can be seen from a study of heights and lengths in Figure 11, the increase resulting from combining the sexes is slight (with the possible exception of waist height and waist back length which were not comparably measured*). Being linear dimensions, they have their strongest relationships with stature, rather than bust or chest circumference. Therefore, it appears that stature can be successfully used to categorize men and women who are sufficiently alike linearly and, since it is possible to accommodate most men and women separately for these linear dimensions using stature as a key dimension, then it will, in all likelihood, be possible to accommodate them in an integrated program for these dimensions as well.

In contrast, a number of non-linear (mass or circumferentially related) dimensions which were comparably measured, have ranges which increase greatly when men and women are combined. As was expected, hip circumference and shoulder circumference are both among them. One marked increase which was not anticipated was found in the ranges of arm circumference at scye. Hip circumference is important to a certain degree in the design of upper body clothing in that the coat, jacket, or shirt must be large enough at the bottom to fit over the larger hips within a size, but it may not be critical that the garment fit closely in this area. In the shoulder/arm area, on the other hand, it is important that garments fit both comfortably and reasonably closely so that movement of the shoulders and arms is not restricted.

In an effort to decrease the combined range widths in the shoulder/arm area, we repeated the foregoing analysis using a new pair of key dimensions. Stature was retained but bust/chest circumference was eliminated with the idea that the difference in the type of tissue involved in the male chest measurement and the female bust measurement might group males and females together who were not sufficiently alike in other areas important to the garment design. Instead, chest circumference at scye (armpit level) was substituted for female bust circumference. Male chest circumference was compared with female chest circumference at scye in hopes that female chest circumference at scye would reflect a torso or frame size more nearly equivalent to that of the male, and result in more homogeneous size groupings.

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* While every effort was made to select comparably measured dimensions for this sizing analysis, certain dimensions, measured somewhat differently in the men's and women's surveys, were deemed too important in clothing design to leave out. They include waist measurements, neck circumference, interscye back and vertical trunk circumference (see Appendix B for detailed descriptions). Comparative analyses and results involving these dimensions were scrutinized with particular care and are not thought to affect the conclusions.

A 20-size chest circumference-at-scye/chest circumference and stature program, with three-inch intervals for chest circumference and four-inch intervals for stature, was established and is illustrated in Figure 12. Population coverage with this program is similar to that for the previous stature/bust-chest circumference program and includes 98.8% of the male sample and 95.2% of the female sample. (To eliminate some confusion when making comparisons, the chest circumference-at-scye/chest circumference and stature program will henceforth be termed "C/C at Scye," and the chest circumference/bust circumference and stature program will be termed "C/C at Bust.")

The combined range width for each size was then computed for the C/C at Scye program and the values for the sizes containing both men and women were averaged. These averages are compared in Table 6 to those computed for the C/C at Bust program. Note that the width of the key dimension size intervals for these two programs are the same; that is, the chest circumference interval is three inches, the stature interval is four inches.

A review of this table indicates that the C/C at Scye program provides smaller average range widths for shoulder breadth, arm circumference at scye, and shoulder circumference, all of which are important areas of an upper body garment. This means that this program groups men and women together who are more alike in these areas than does the C/C at Bust program.

For other dimensions, such as hip breadth and hip circumference, the table indicates that the men and women grouped together in the C/C at Scye program differ even more than do the men and women grouped together in the C/C at Bust program. Since these dimensions are not critically important to upper body garments, it was concluded that the C/C at Scye program provided somewhat better results for upper body garments than did the C/C at Bust program. Despite the improvements, however, the ranges in the shoulder and arm related areas are still considered larger than would be desirable for a well-fitting size program.

In an effort to further improve upon this within-a-size variance, it was decided to try a slightly unorthodox approach and select a mass-related key dimension from among those measurements which present the greatest discrepancies. As a result, we chose shoulder circumference to pair with stature in a 20-size program, with three-inch intervals in shoulder circumference and four-inch intervals in stature. The program is shown on a bivariate in Figure 13. The coverage within the size categories (95.9% of the men and 98.8% of the women) is equivalent to that obtained in the previously described programs.

Again, the combined range width for each size was computed and the sizes averaged. The average range width values for the shoulder circumference and stature program (ShC) are compared to those from the other two programs in Table 7. For arm circumference at scye, the ShC program has a smaller range width, by approximately one inch, than the C/C at Bust program, and by approximately one-half inch than the C/C at Scye program. The range width for shoulder circumference is, of course, much smaller since

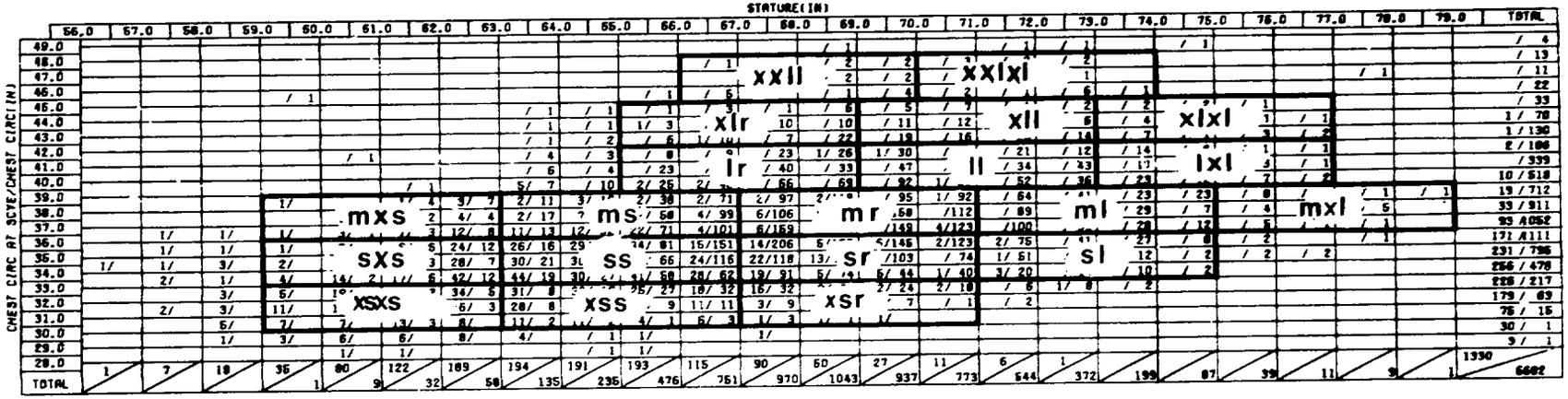

Figure 12. An illustration of size categories for a 20-size chest circumference-at-scye/chest circumference and stature program (1977 Army women/1966 Army men).

TABLE 6

COMPARISON OF AVERAGE COMBINED RANGE WIDTHS*

Variable	AVERAGE COMBINED RANGE WIDTHS C/C at Bust	C/C at Scye	Diff**
Weight	44.98	46.50	1.52
HEIGHTS & LENGTHS			
Shoulder-Elbow Lgth	2.00	1.96	-0.04
Shoulder Height	4.16	4.19	0.03
Sleeve Inseam	2.68	2.67	-0.01
Stature	3.82	3.82	0.00
Waist Back Lgth	4.30	4.22	-0.08
Waist Height	5.53	5.49	-0.04
ARCS AND BREADTHS			
Chest Breadth	1.85	1.81	-0.04
Hip Breadth	3.93	4.23	0.30
Interscye Back	3.50	3.49	-0.01
Shoulder Breadth	2.53	2.24	-0.29
Shoulder Length	2.53	2.53	0.00
CIRCUMFERENCES			
Arm Circ at Scye	4.58	4.05	-0.53
C/C at Bust or Scye	2.86	2.86	0.00
Hip Circ	8.33	9.45	1.12
Neck Circ	3.46	3.15	-0.31
Shoulder Circ	7.72	6.10	-1.62
Vert Trunk Circ	8.03	8.04	-0.01
Waist Circ	8.18	7.04	-1.14
Wrist Circ	1.50	1.39	-0.11

* Units are inches or pounds.
** Negative sign indicates C/C at Scye value is smaller.

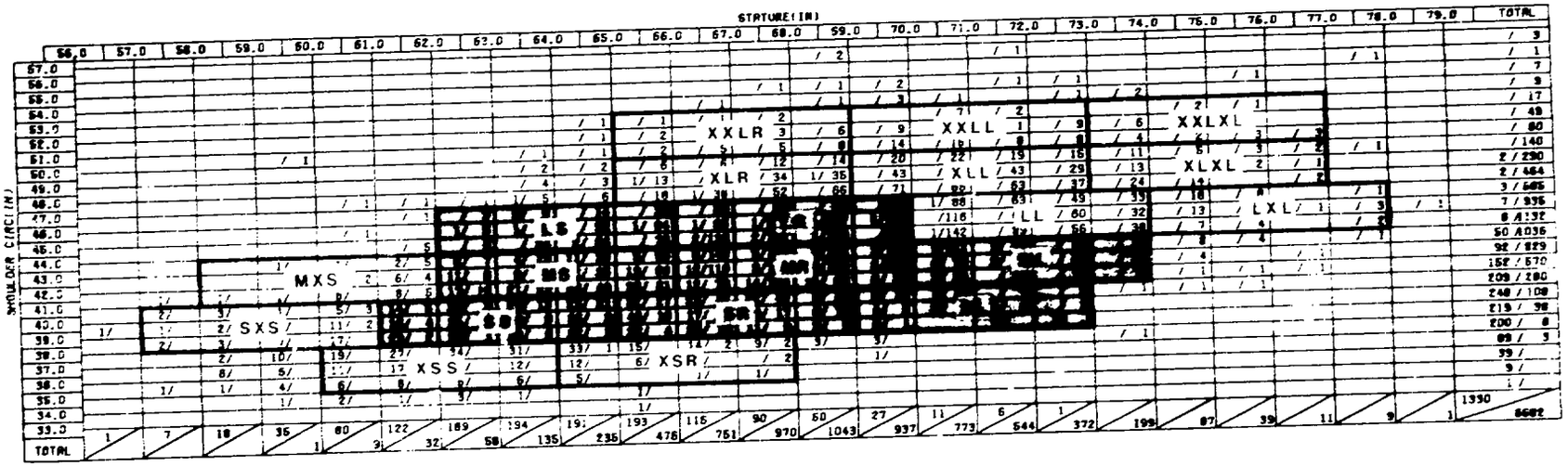

Figure 13. An illustration of size categories for a 20-size shoulder circumference and stature program (1977 Army women/1966 Army men). Shaded areas are size categories based on integrated data.

TABLE 7

COMPARISON OF AVERAGE RANGE WIDTHS*

Variable	RANGE WIDTH C/C at Bust	ShC	Diff**	RANGE WIDTH C/C at Scye	ShC	Diff**
Weight	44.98	58.20	13.22	46.50	58.20	11.70
HEIGHTS AND LENGTHS						
Shoulder-Elbow Lgth	2.00	1.92	-0.08	1.96	1.92	-0.04
Shoulder Height	4.16	4.23	0.07	4.19	4.23	0.04
Sleeve Inseam	2.68	2.63	-0.05	2.67	2.63	-0.04
Stature	3.82	3.82	0.00	3.82	3.82	0.00
Waist Back Lgth	4.30	4.14	-0.16	4.22	4.14	-0.08
Waist Height	5.53	5.44	-0.09	5.49	5.44	-0.05
ARCS AND BREADTHS						
Chest Breadth	1.85	2.20	0.35	1.81	2.20	0.39
Hip Breadth	3.93	4.55	0.62	4.23	4.55	0.32
Interscye Back	3.50	3.90	0.40	3.49	3.90	0.41
Shoulder Breadth	2.53	2.28	-0.25	2.24	2.28	0.04
Shoulder Lgth	2.53	2.47	-0.06	2.53	2.47	-0.06
CIRCUMFERENCES						
Arm Circ at Scye	4.58	3.60	-0.98	4.05	3.60	-0.45
C/C at Bust or Scye	2.86	7.80	4.98	2.86	7.80	4.98
Hip Circ	8.33	10.67	2.34	9.45	10.67	1.22
Neck Circ	3.46	2.76	-0.70	3.15	2.76	-0.39
Shoulder Circ	7.72	2.86	-4.86	6.10	2.86	-3.24
Vert Trunk Circ	8.03	8.86	0.83	8.04	8.86	0.82
Waist Circ	8.18	8.17	-0.01	7.04	8.17	1.13
Wrist Circ	1.50	1.27	-0.23	1.39	1.27	-0.12

* Units are inches or pounds.
** Negative sign indicates ShC value is smaller.

it is now a key dimension, and the neck circumference range is considerably narrower as well. Neck circumference is among those dimensions not comparably measured and, as a result, was given special scrutiny. An examination of the measurement differences still suggested that the males and females who are more similar in actual neck circumference are being grouped together in this sizing system.

Interscye back is another "noncomparable" dimensions and this dimension shows an increase in the combined range width using the ShC system. While this may seem surprising, it is likely to be due to the difference in original measurement techniques.

Figure 14 was prepared to illustrate the relationships between the male and female dimensions in this program.

Assuming that the male-only program currently in use for the combat coat is effective in accommodating male Army personnel, it follows that the male part of the C/C at Bust program outlined in this report will accommodate at least the males just as well, if not better, since key dimensions are the same and the size category widths, for the most part, are smaller in the C/C at Bust program. This being the case, the male range widths from the C/C at Bust program were used as the basis for a comparison with the combined range widths of the proposed ShC program for the purpose of assessing how well the integrated ShC program would accommodate both men and women. These values are compared in Table 8.

The results are quite encouraging. Most dimensions in the ShC program have combined range widths which are only slightly larger than the male range width. Of 20 dimensions, there are only eight which have combined range widths greater than one-half inch larger and these are, for the most part, in less critical areas for coat sizing. It is our conclusion, therefore, that the 20-size upper body program based on the sizing dimensions of stature and shoulder circumference offers a significant improvement over the alternative key dimensions considered in grouping men and women into an integrated upper body sizing system.

Before proceeding to the final step in the development of a sizing program--selection of recommended design values--it may be useful to pause and examine our data to assure that statistical manipulations have not impaired their realism.

Combined range statistics are the basic building blocks of our integrated sizing programs. Since these values are arrived at by using regression equations, rather than directly computed, we examined a number of computer printouts, such as that illustrated in Figure 15, to establish that the proposed range of sizes for selected dimensions from the 20-size program would, in fact, accommodate the intended population.

This printout illustrates the actual distribution of a given dimension, in this instance shoulder breadth, within each size. The size category is listed in the column at the left; the dimension scale is listed across the top. The numbers in each row next to each size represent the persons in

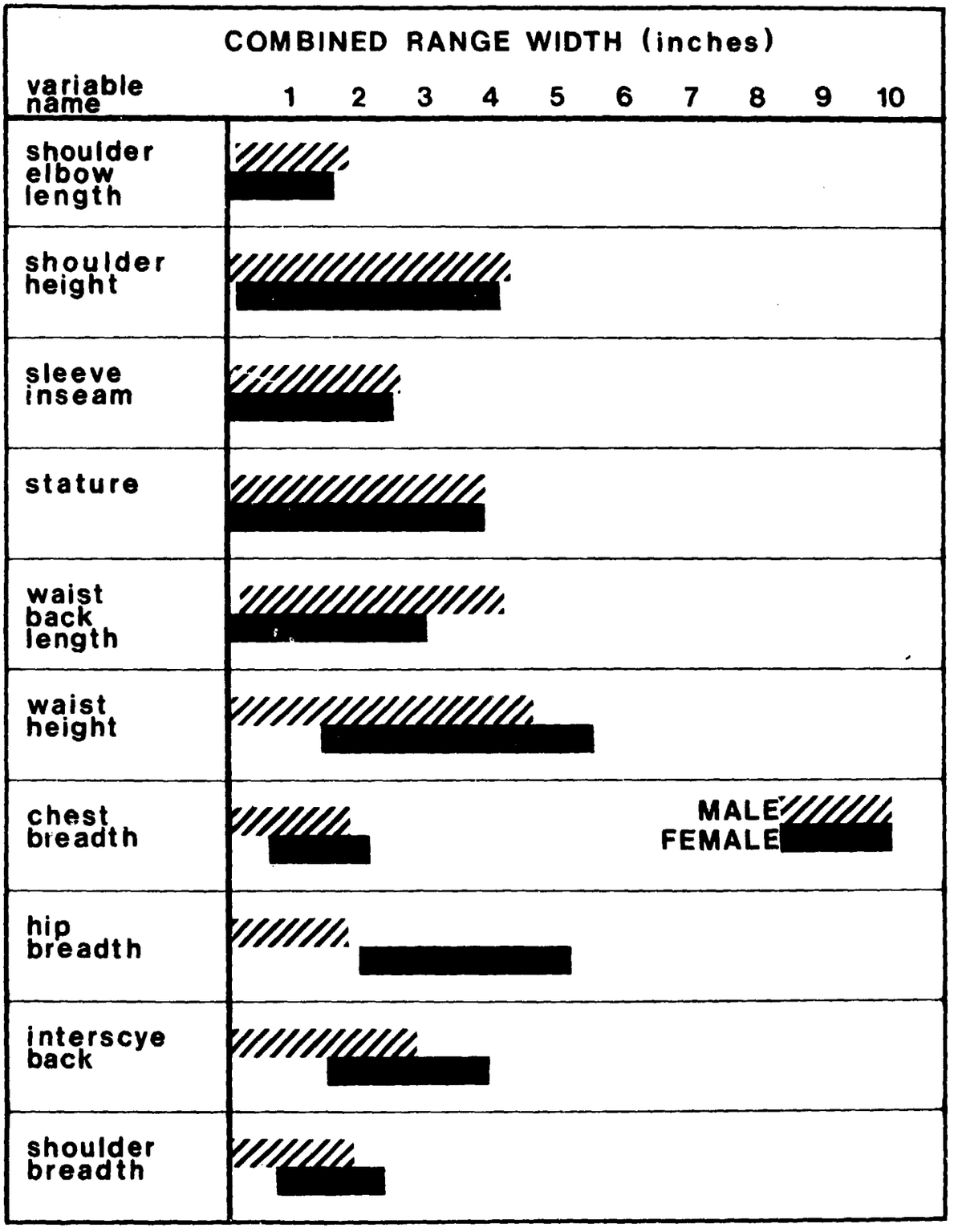

Figure 14. Comparison of average combined range widths and separate male and female range widths, 20-size shoulder circumference and stature program.

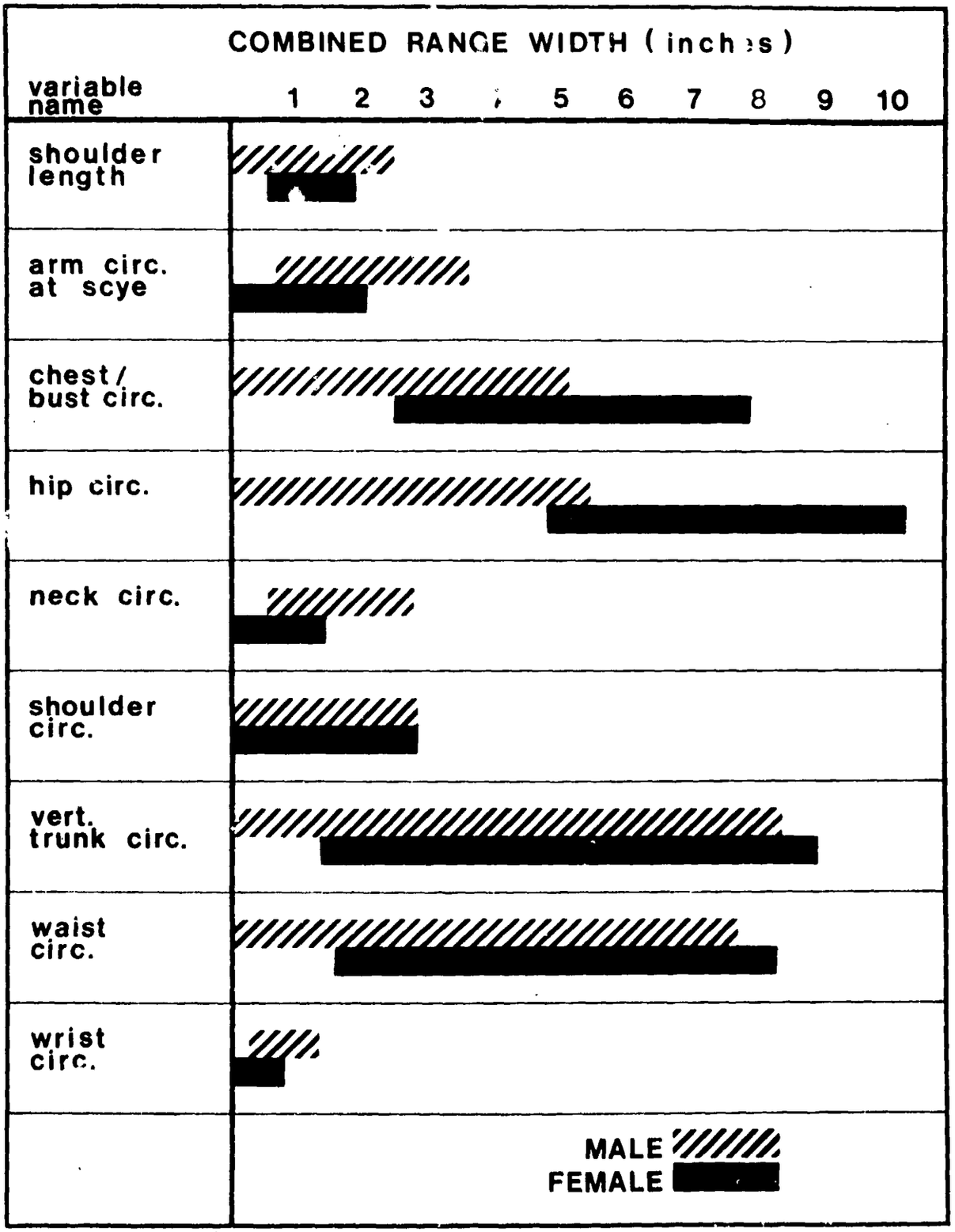

Figure 14. (cont'd)

TABLE 8

COMPARISON OF RANGE WIDTH VALUES*

Variable	C/C at Bust Male	ShC Combined	Diff
Weight	42.90	58.20	15.30
HEIGHTS & LENGTHS			
Shoulder-Elbow Lgth	1.79	1.92	0.13
Shoulder Height	4.16	4.23	0.07
Sleeve Inseam	2.63	2.63	0.00
Stature	3.82	3.82	0.00
Waist Back Lgth	4.07	4.14	0.07
Waist Height	4.60	5.44	0.84
ARCS AND BREADTHS			
Chest Breadth	1.73	2.20	0.47
Hip Breadth	1.86	4.55	2.69
Interscye Back	3.40	3.90	0.50
Shoulder Breadth	2.18	2.28	0.10
Shoulder Lgth	2.53	2.47	-0.06
CIRCUMFERENCES			
Arm Circ at Scye	3.25	3.60	0.35
Bust/Chest Circ	2.86	7.80	4.94
Hip Circ	5.18	10.67	5.09
Neck Circ	2.17	2.76	0.59
Shoulder Circ	4.83	2.86	-1.97
Vert Trunk Circ	8.03	8.86	0.83
Waist Circ	6.94	8.17	1.23
Wrist Circ	0.95	1.27	0.32

* Units are inches and pounds.
** Negative sign indicates ShC program combined range width is smaller than C/C at Bust program male range width.

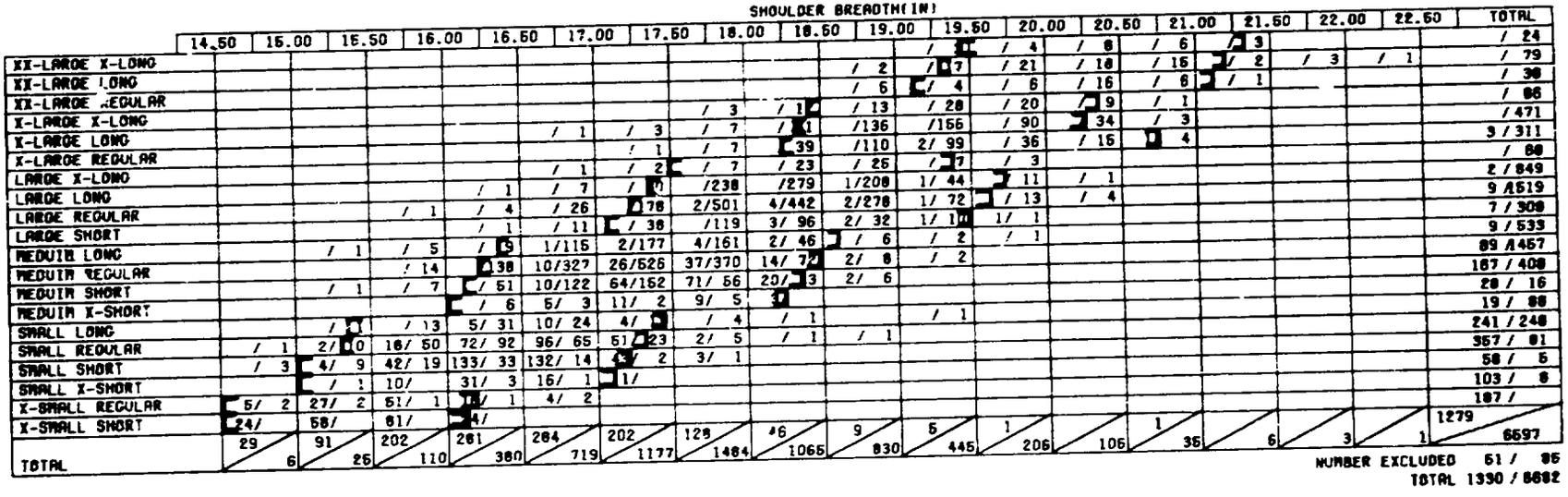

Figure 15. Bivariate frequency illustrating shoulder breadth coverage provided by 20-size shoulder circumference/stature sizing program (1977 Army women/1966 Army men).

the category and their distribution with respect to the given dimension. The brackets encompass the combined "range to be accommodated" for each size. As can be seen, the number of persons within the brackets is a very close approximation of the intended 90%-or-better coverage. This is also true of the separate male and female "range to be accommodated." Note that there are no women in six of the seven largest sizes; this can quickly be determined from the column of totals at the right of the table. For these categories the brackets represent the male range width only.

Having established that this shoulder circumference and stature program provides the most reasonable results, it still remained to determine design or sizing values that will best accommodate the individuals within each size for each body dimension.

Three factors were considered in the derivation of the design values:

- The design value must be sufficiently large to accommodate most persons within a size.
- The design values must be additive--that is, recommended values for various parts of the garment must add up to the desired whole when the garment is assembled.
- Design values necessary to accommodate both sexes are only used in categories which include sufficient numbers of people from both sexes.

We began by determining which size categories must be integrated. Referring again to Figure 13, the eight shaded categories were selected for integration. Of those remaining, four were designated "female" categories for which only the females would be considered when selecting design values due to the scarcity of males in those sizes, and eight were designated "male" categories. Figures 16 and 17 illustrate this configuration of sizes with respect to each separate distribution of Army men and women. As can be seen, the majority of persons of each sex are included within the sizing categories. In fact, 95.6% of all the women fall within either a "female" or an "integrated" size category and 98.3% of all the males fall within either a "male" or an "integrated" category.

It should also be noted that although a category is designated "male" and only the dimensions of the males within that category will be considered, it is still possible that if a few females happen to fall in that size category, they may be accommodated by that size or in one of the adjacent integrated size categories. The same is true of any males who may fall in the female-designated size categories. The major advantage of this approach is that for males in those sizes designated "male," and for females in those sizes designated "female," the design should allow the clothing to fit better than if the size were to be designed to consider both sexes.

Since it is axiomatic that smaller persons can, if necessary, wear larger garments but larger persons cannot be accommodated by too small

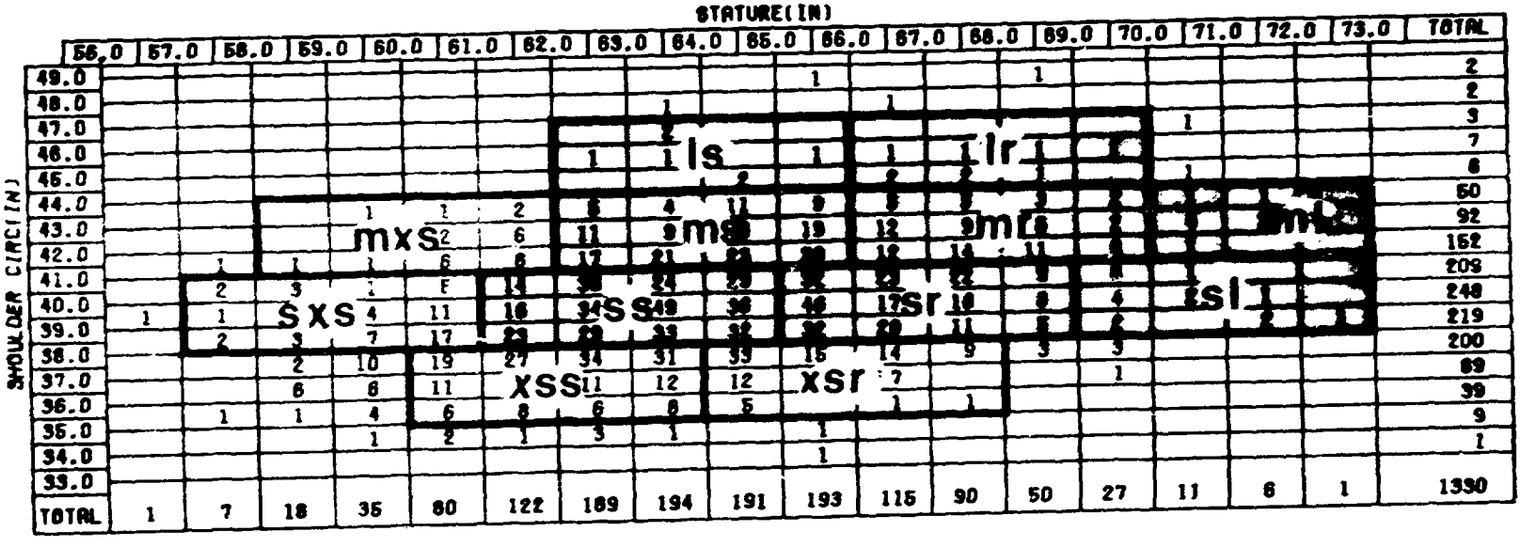

Figure 16. The size categories designated "female" (unshaded) and those to be integrated (shaded) illustrated on a 1977 Army females bivariate plot.

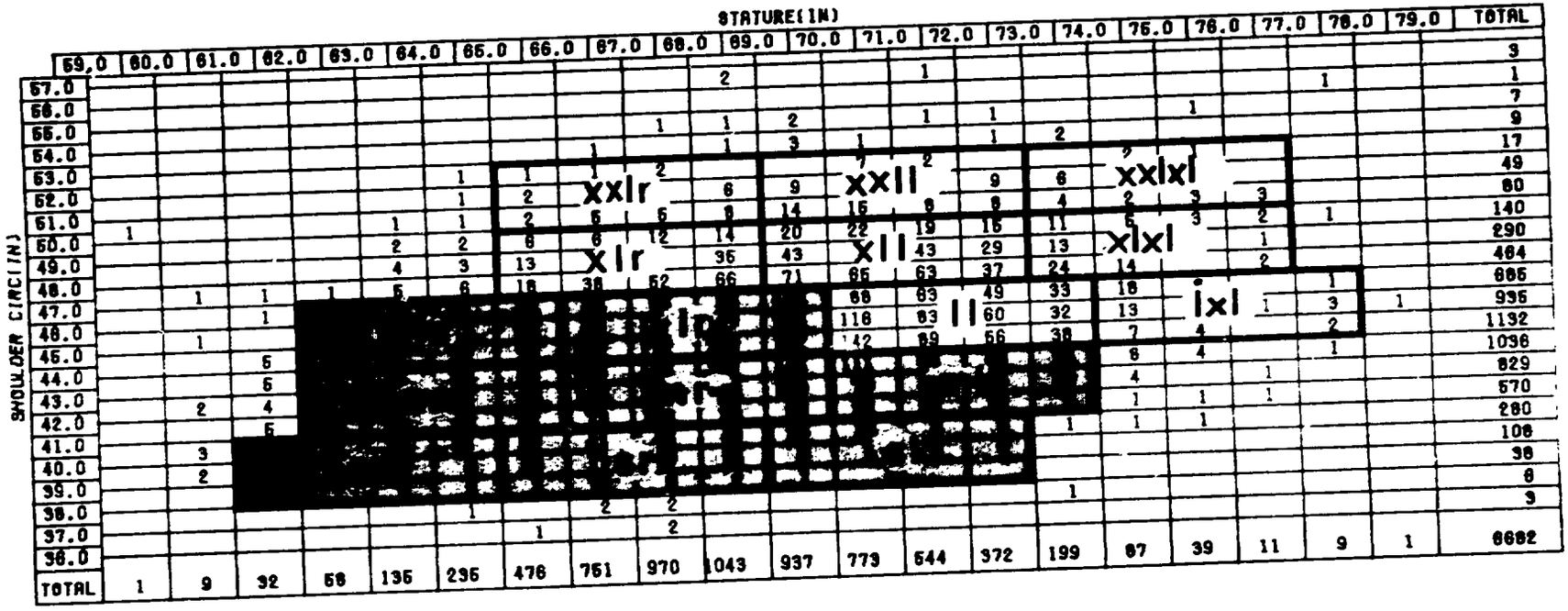

Figure 17. The size categories designated "male" (unshaded) and those to be integrated (shaded) illustrated on a 1966 Army males bivariate plot.

garments, upper range values are usually selected as the design values since they accommodate the majority of the individuals' values within that size category. However, due to the nature of the statistical basis from which they are derived and the less-than-perfect correlation among the dimensions of the body, the values at the upper end of the "range to be accommodated" as computed here are not additive. This problem is the same as that which occurs when using percentile values and has been discussed in previous reports (McConville and Churchill, 1976;[13] Robinette and Churchill, 1979[14]).

We have, therefore, devised an alternate means for deriving sizing values which are additive. The recommended sizing value for each dimension and each size was calculated from regression equations using the key dimensions as predictor variables. Once, again, to accommodate the maximum number of persons, the recommended values are computed for an individual who falls at the upper point in each size category. The regression equations are computed from each separate sample making this process straightforward for the categories designated as "male or "female," but resulting, of course, in <u>two</u> values in those categories to be integrated.

To arrive at a single design value for the integrated size categories, we classified the dimensions as to type (length, breadth, or circumference) and by area of the body (shoulders or hips, for example) and chose either male or female values depending on which were predominantly larger. Thus, shoulder, upper arm, and reach dimensions are largely derived from male values while hip dimensions and several other torso circumferences are derived from female dimensions. The purpose of this approach was to maintain consistency in the choice of data so as to arrive at values which are additive for the construction of garments.

Table 9 is the output for size Medium Regular. The recommended sizing value for each dimension is listed in the row of the sex from which it is derived. Thus, for example, shoulder height is listed in the male row, as are all the height dimensions. This indicates that the heights were predicted from the male regression equations. By using the male equations for all the heights, the values will be additive. In the hip area, female values were used since the females are larger in this area.

These values do not represent the final pattern or garment sizes, but the nude body dimensions which should be accommodated by the garment or pattern. Appropriate amounts should be added to these values to allow for tailoring increments, such as easing and seam allowances.

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[13]McConville, John T. and Edmund Churchill, 1976, <u>Statistical Concepts in Design</u>, AMRL-TR-76-29, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD A025 750)

[14]Robinette, Kathleen and Thomas Churchill, 1979, <u>Design Criteria for Characterizing Individuals in the Extreme Upper and Lower Body Size Ranges</u>, AMRL-TR-79-33, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD A072 353)

TABLE 9

20-SIZE PROGRAM FOR THE UPPER BODY*
MEDIUM REGULAR

The Range for Stature 66.00 - 69.99
The Range for Shoulder Circumference 41.00 - 43.99

Males n=1457 Tariff Percentage = 22.10%
Females n= 89 Tariff Percentage = 6.97%

Variable	Sex	Mid-Size Value	SZ-SD	Range to be Accommodated	Recommended Value
Weight	M	142.63	13.60	120.19-165.07	
	F	159.86	10.91	141.85-177.86	
HEIGHTS AND LENGTHS					
Shoulder-Elbow Lgth	M	14.33	0.54	13.43-15.23	14.77
	F	14.09	0.47	13.32-14.87	
Shoulder Height	M	55.91	1.27	53.81-58.01	57.72
	F	56.05	1.17	54.13-57.98	
Sleeve Inseam	M	18.92	0.80	17.60-20.23	19.51
	F	18.88	0.77	17.62-20.15	
Stature	M	68.00	1.15	66.09-69.90	
	F	68.00	1.15	66.09-69.90	
Waist Back Lgth	M	17.42	1.23	15.39-19.45	17.94
	F	16.93	0.92	15.41-18.45	
Waist Height	M	41.43	1.39	39.13-43.73	42.77
	F	42.60	1.23	40.57-44.63	
ARCS AND BREADTHS					
Chest Breadth	M	11.49	0.56	10.56-12.41	
	F	11.96	0.47	11.18-12.73	12.38
Hip Breadth	M	12.63	0.58	11.67-13.59	
	F	14.95	0.78	13.66-16.24	15.47
Interscye Back	M	14.73	0.98	13.11-16.35	15.21
	F	15.81	0.74	14.59-17.03	
Shoulder Breadth	M	17.15	0.57	16.21-18.08	17.71
	F	17.76	0.44	17.03-18.49	
Shoulder Length	M	6.19	0.75	4.95- 7.42	6.37
	F	6.22	0.38	5.59- 6.86	

* Units are inches or pounds.

Table 9 (continued)

20-SIZE UPPER BODY
MEDIUM REGULAR

Variable	Sex	Mid-Size Value	SZ-SD	Range to be Accommodated	Recommended Value
CIRCUMFERENCES					
Arm Circ at Scye	M	16.83	0.99	15.20-18.46	17.40
	F	15.93	0.65	14.87-17.00	
Biceps Circ/Flexed	M	12.01	0.73	10.80-13.21	12.47
	F	11.51	0.63	10.46-12.55	
Bust/Chest Circ	M	35.07	1.57	32.48-37.67	
	F	37.53	1.65	34.80-40.25	38.93
Hip Circumference	M	35.52	1.65	32.80-38.24	
	F	40.62	1.80	37.65-43.59	42.15
Neck Circumference	M	14.26	0.65	13.19-15.34	14.61
	F	13.41	0.48	12.61-14.21	
Shoulder Circ	M	42.50	0.86	41.07-43.92	43.99
	F	42.50	0.86	41.07-43.92	
Vertical Trunk Circ	M	62.97	2.51	58.82-67.11	
	F	64.50	1.97	61.24-67.75	66.51
Waist Circ	M	29.65	2.34	25.79-33.51	
	F	30.64	1.96	27.41-33.88	31.99
Wrist Circ	M	6.56	0.28	6.09- 7.03	6.73
	F	6.10	0.21	5.75- 6.45	

Lower Body

The sizing analysis of the lower body followed the procedure used for the upper body. Again, the selection of key dimensions to be evaluated began with those used in the male-only program described in MIL-T-4407,[15] (see Figure 2). These were waist circumference and inseam length (for which we substituted crotch height, since that was the actual dimension measured on the army samples). Again, a 20-size program was selected from among several alternatives studies (see Figure 18). This program has three-inch intervals of crotch height and four-inch intervals of waist circumference. The twenty sizes encompass 95.3% of the female sample and 99.4% of the male sample.

Next, the dimensional data were computed for each size for each sex and the separate "range to be accommodated" values were overlapped to determine the combined ranges. The separate and combined average range widths for the twenty size categories are presented in Table 10, as are the average ranges as a percentage of the male and female ranges for each lower body dimension.

TABLE 10

COMPARISON OF SEPARATE AND COMBINED RANGES FOR THE 20-SIZE WAIST CIRCUMFERENCE AND CROTCH HEIGHT PROGRAM
(Units are inches or pounds)

Variable	AVERAGE RANGE WIDTH			Average (%) Cost of Accommodation	
	Male	Female	Combined	Male	Female
Weight	46.60	40.15	48.15	103	120
HEIGHTS & LENGTHS					
Calf Height	2.97	2.03	2.99	101	147
Crotch Height	2.86	2.86	2.86	100	100
Kneecap Height	3.24	2.08	3.25	100	156
Stature	5.66	5.59	6.35	112	114
Waist Height	4.62	4.38	5.56	120	127
CIRCUMFERENCES & BREADTHS					
Ankle Circ	1.63	1.51	1.97	121	130
Calf Circ	2.80	2.83	3.04	109	107
Hip Breadth	1.85	2.69	4.11	222	153
Hip Circ	4.92	6.22	8.98	183	144
Upper Thigh Circ	4.40	4.59	6.96	158	152
Waist Circ	3.82	3.82	3.82	100	100

[15] See reference 4.

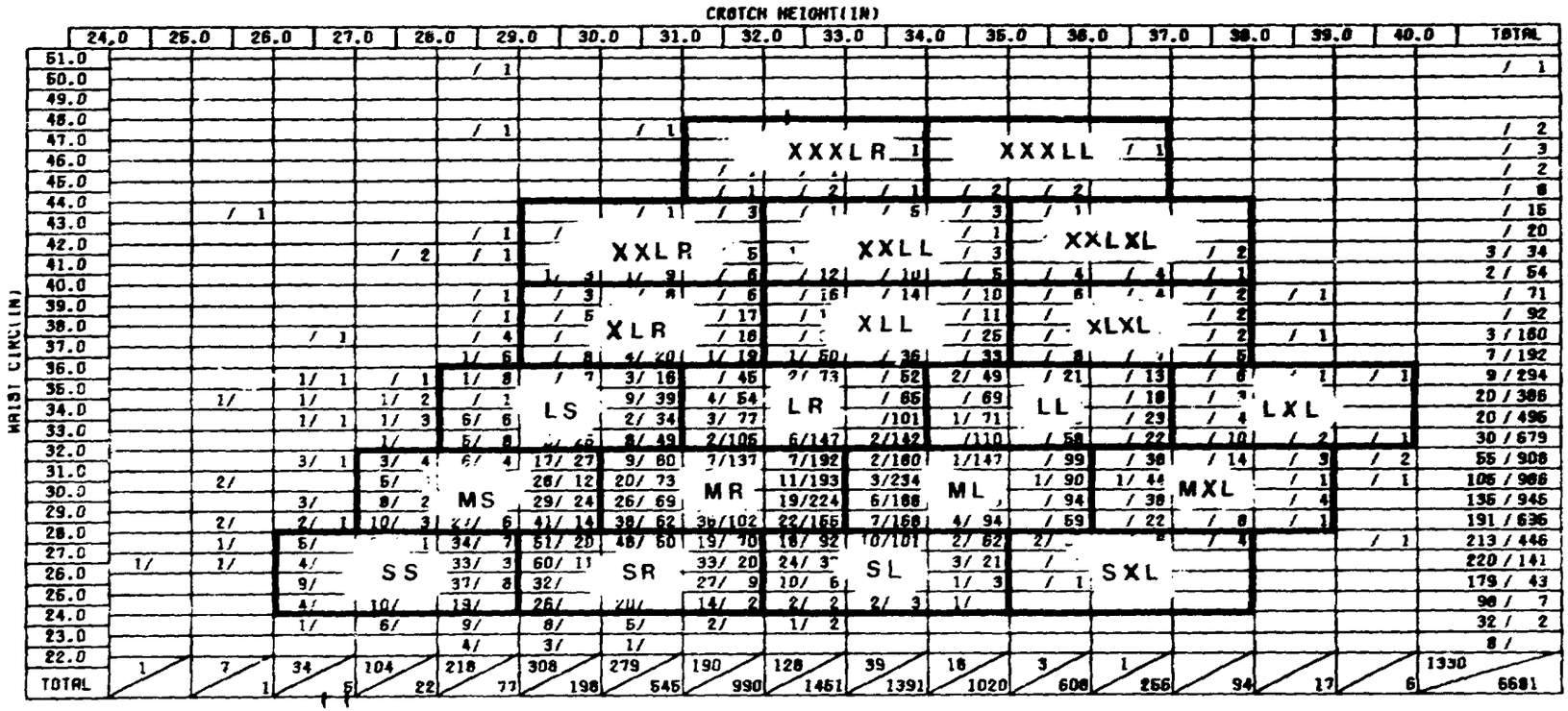

Figure 18. An illustration of size categories for a 20-size waist circumference and crotch height program (1977 Army women/1966 Army men).

The linear dimensions (heights and lengths) once again seem to be well controlled by crotch height so that the combined range is not much larger than the male range. The females seem to be somewhat less variable than the males for these dimensions and their variance seems to be almost completely overlapped by the males.

Stature has a moderately large combined range width compared with men's and women's ranges separately, probably due to the fact that crotch height only controls a certain portion of body stature. Stature, however, is not of critical importance in a lower body garment. Waist height has a somewhat large combined range width with respect to the separate single-sex ranges but this is probably an artifact of the difference in the definition of waist which has caused the females to be larger, on the average, within a size. Crotch height was thus deemed acceptable as a key dimension.

If the linear dimensions seem to be reasonably under control, the picture with respect to the circumference and breadths is quite the opposite, as can be seen in Table 10. The increases resulting from a combination of the sexes in these dimensions are considerable, both in inches and in percentages. The hip and upper leg areas are of crucial importance in a lower body garment. While the finished waist on a garment can be made adjustable (with the use of elastic material, belts, or alternate fasteners), hip and upper leg areas cannot.

In an attempt to improve the sizing in these areas of the body, an alternative program was created retaining crotch height as a key dimension and using hip circumference as a replacement for waist circumference as the other key dimension. This 20-size program used the same size interval widths for crotch height as in the previous program (three inches) but employed a three-inch interval for hip circumference as opposed to the four-inch interval used for the waist circumference. Despite the reduction in the interval width for hip circumference, the 20 sizes encompass some 99.0% of both the male and the female samples. This program is illustrated in Figure 19. Again, the range of accommodation for the various lower body dimensions were computed, averaged, and compared to comparable values developed for the previous crotch height/waist circumference sizing program. The results of this comparison are shown in Table 11.

The changes in the average range width for linear dimensions can be seen to be relatively smaller, the largest changes being for stature and waist height which were discussed previously. The mass-related changes, however, show significant differences. As would be expected with the use of a hip measurement as a key dimension, the hip circumference, hip breadth and thigh circumference are all significantly reduced while the average range width of waist circumference radically increases. Despite this fact, the crotch height/hip circumference program appears to offer a major advantage over the crotch height/waist circumference sizing program in that adjustability in the waist area of a garment will be easier to achieve than a comparable degree of adjustability in the hip-thigh area of a garment. This program,

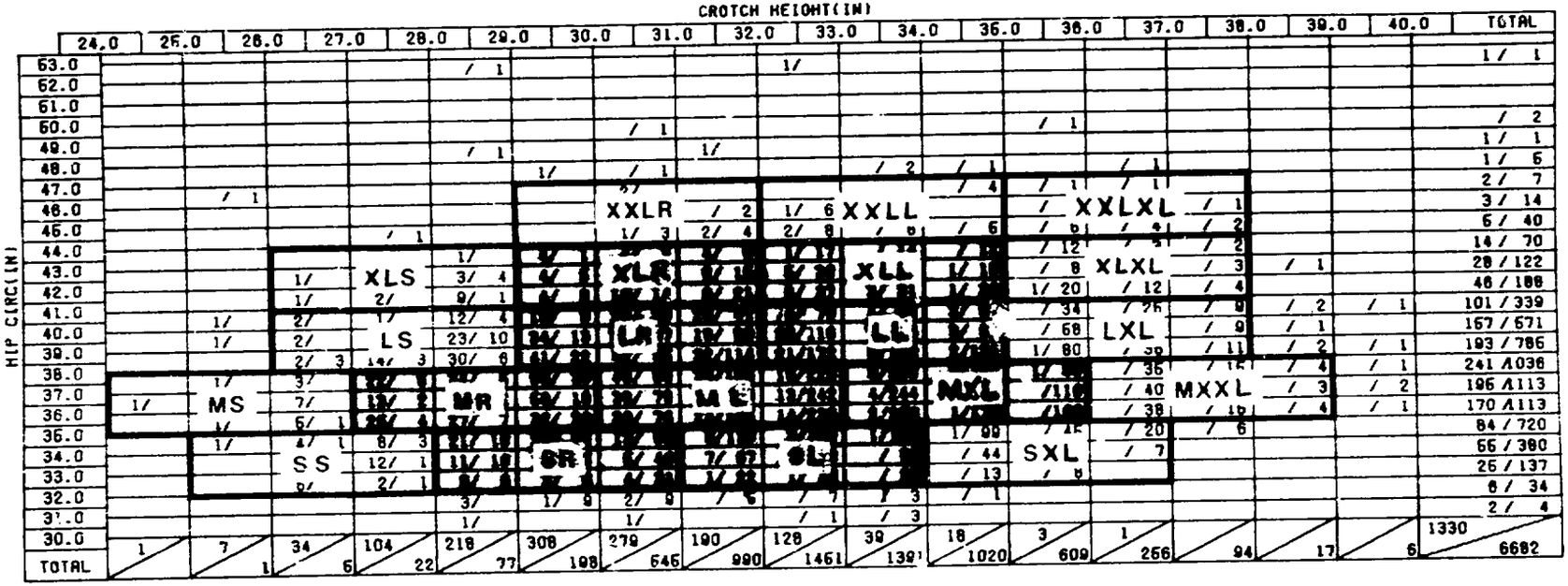

Figure 19. An illustration of size categories for a 20-size hip circumference and crotch height program (1977 Army women/1966 Army men).

TABLE 11

COMPARISON OF AVERAGE RANGE WIDTHS*
(Inches or Pounds)

Variable Name	Waist C/ Crotch Ht Mean	Hip C/ Crotch Ht Mean	Diff Mean
Weight	48.15	63.73	15.58
HEIGHTS & LENGTHS			
Calf Height	2.99	2.96	-0.03
Crotch Height	2.86	2.86	0.00
Kneecap Height	3.25	3.30	0.05
Stature	6.35	6.72	0.37
Waist Height	5.56	5.18	-0.38
CIRCUMFERENCES & BREADTHS			
Ankle Circ	1.97	2.24	0.27
Calf Circ	3.04	3.25	0.21
Hip Breadth	4.11	2.49	-1.62
Hip Circ	8.98	2.86	-6.12
Upper Thigh Circ	6.96	3.75	-3.21
Waist Circ	3.82	11.58	7.76

* Only sizes containing both men and women were used to compute average range widths.

then, should result in a potentially better fitting garment for a larger number of wearers.

Using the crotch height/hip circumference sizing program, described above, the twenty size categories were designated as male, female, or integrated for computational purposes, based on the relative frequency of men or women who fell within the boundaries of each size. As with the upper garment sizing system, the designation of a size category as male does not mean that no women fall within the boundaries of the size category. It does mean, however, that the numbers of the opposite sex are so infrequent as to essentially be disregarded in computing sizing values for that category. Such individuals may well be accommodated by a garment in that size category or by one from an adjacent integrated size. Five categories were designated female, six categories male, and eight integrated. The female and integrated size categories are illustrated in Figure 20 and the male and integrated sizes illustrated in Figure 21.

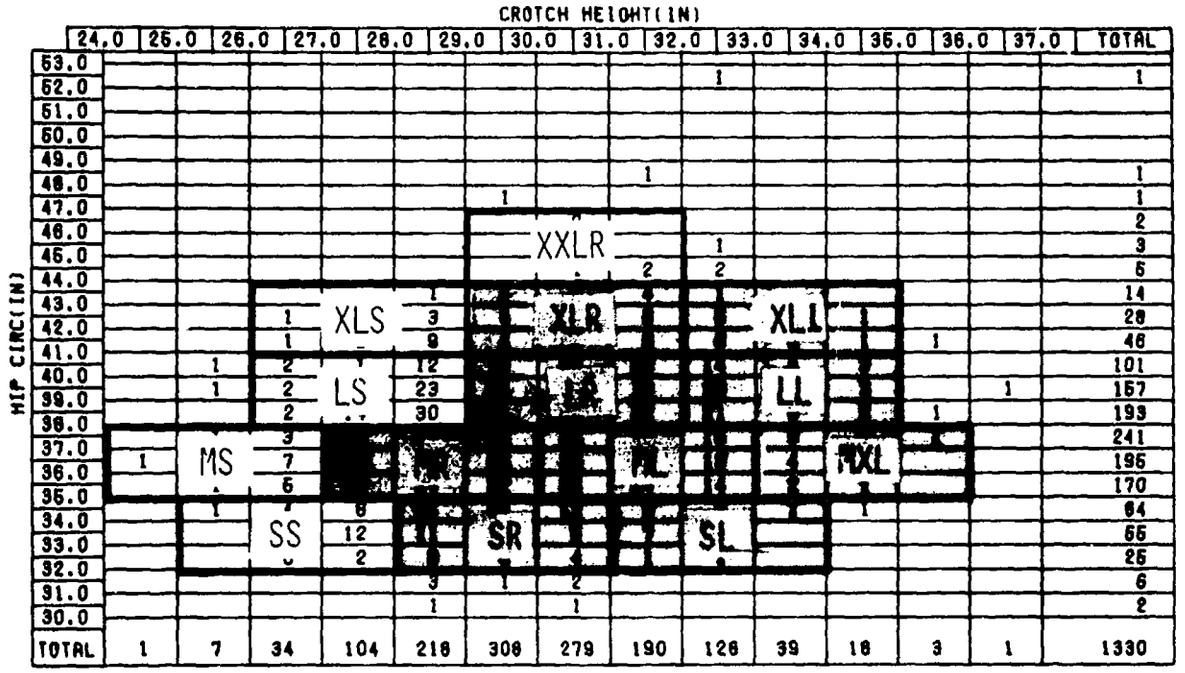

Figure 20. The categories designated "female" (unshaded) or "integrated" (shaded) illustrated on a 1977 Army females bivariate plot.

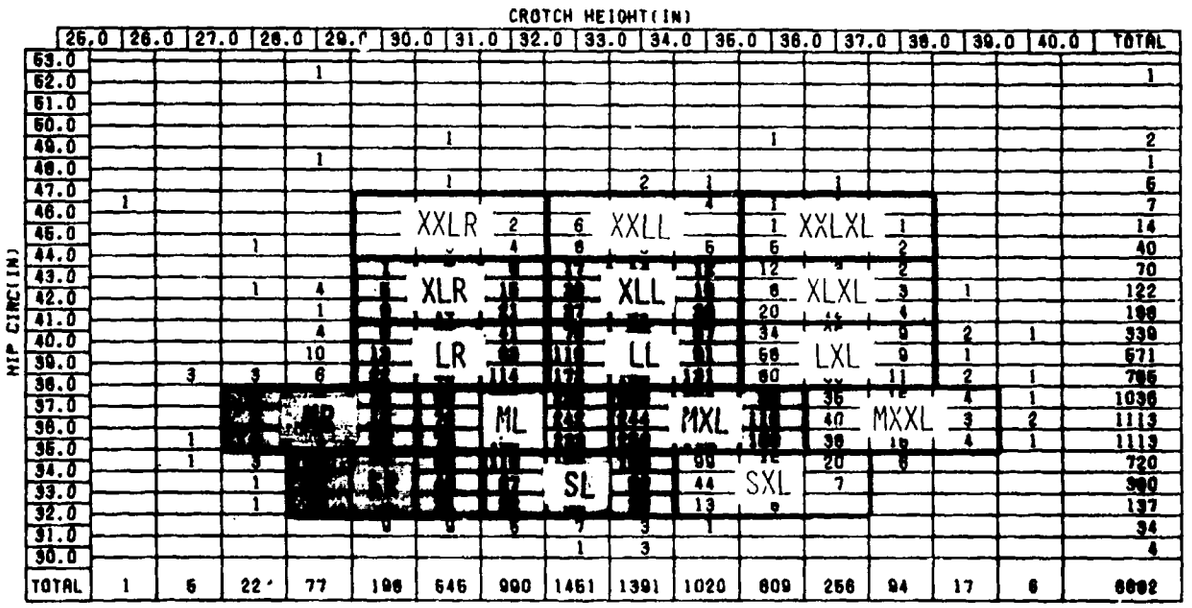

Figure 21. The categories designated "male" (unshaded) or "integrated" (shaded) illustrated on a 1966 Army males bivariate plot.

As with the upper body size system, the mean, the within-a-size standard deviation, the range to be accommodated and a recommended design value were computed for each body dimension in each size category. A typical output from these data is shown in Table 12, the Medium Regular size. These values were computed from regression equations from female data for the female-designated sizes and from male data for male-designated sizes. The integrated sizes use a recommended design value based on either the male or female data set as appropriate--that is, whichever set of values was larger for the most part for that particular area of the body.

As noted in the Introduction to this report, detailed anthropometric sizing programs for the upper and lower body have been developed and are reported in a companion volume (Robinette, Churchill and Tebbetts, 1981).[16]

[16]See reference 5.

TABLE 12

20-SIZE PROGRAM FOR THE LOWER BODY*
MEDIUM REGULAR

The Range for Crotch Height 27.00 - 29.99
The Range for Hip Circumference 35.00 - 37.99

Males n=123 Tariff Percentage = 1.86%
Females n=315 Tariff Percentage = 23.92%

Variable	Sex	Mid-Size Value	SZ-SD	Range to be Accommodated	Recommended Value
Weight	M	145.20	12.20	125.06-165.33	
	F	121.97	9.41	106.44-137.51	
HEIGHTS					
Calf Height	M	12.38	0.90	10.90-13.86	12.96
	F	12.10	0.61	11.10-13.11	
Crotch Height	M	28.50	0.87	27.07-29.93	30.00
	F	28.50	0.87	27.07-29.93	
Kneecap Height	M	18.56	0.98	16.95-20.17	19.41
	F	17.98	0.63	16.94-19.01	
Stature	M	63.44	1.65	60.71-66.17	
	F	62.04	1.60	59.40-64.68	
Waist Height	M	37.51	1.38	35.24-39.79	39.16
	F	38.23	1.29	36.11-40.35	
CIRCUMFERENCES AND BREADTHS					
Ankle Circ	M	8.71	0.45	7.96- 9.46	8.97
	F	8.00	0.41	7.32- 8.69	
Calf Circ	M	14.23	0.76	12.98-15.47	14.70
	F	13.51	0.72	12.32-14.71	
Hip Breadth	M	12.68	0.46	11.92-13.44	
	F	13.54	0.51	12.70-14.38	14.06
Hip Circ	M	36.50	0.87	35.07-37.93	
	F	36.50	0.87	35.07-37.93	38.00
Upper Thigh Circ	M	21.76	1.14	19.89-23.62	
	F	21.76	0.95	20.20-23.33	22.68
Waist Circ	M	31.60	1.97	28.35-34.84	33.07
	F	27.21	2.02	23.88-30.53	

* Units are inches or pounds.

Section IV

CONCLUSION AND RECOMMENDATIONS

The challenge in developing an integrated male-female sizing system for Army field clothing lies not only in accommodating the considerable differences in overall body size which occur in a large heterogeneous population of men and women, but in solving the more serious problems arising from differences in proportionality which exist even among males and females of the same height and weight. In terms of clothing design, the most serious of these proportional discrepancies are found in the shoulders and hips.

The approach used here was to identify key sizing dimensions which exerted some level of control on the variations of body size and proportionality found between the sexes in those areas of the body critical to the fit of clothing. Alternate pairs of key dimensions were tested to determine which combinations provided optimum control and it was concluded that key dimension sets which incorporated the critical shoulder and hip dimensions offered the most promise. Thus, stature and shoulder circumference were established as the basis for sizing upper-body garments, and crotch height and hip circumference were established for lower body sizing programs.

A system of 20 sizes was selected for both upper- and lower-body clothing with a view toward maximum reduction of within-a-size variation on the one hand and production of the minimum number of sizes on the other. Statistically, the male and female data were kept separate in the sizing analysis and resulted in three different types of size category: "female" sizes for those smaller size categories in which very few men were found, "male" sizes at the upper end of the range in which very few women were found, and integrated sizes for which values were computed by combining the separate size ranges of men and women who fell into those categories. The use of discrete male and female values in the data analysis and determination of size values appears to assure the best possible fit for the persons most likely to be found in each size category.

The sizing programs developed by the means described in this report are, as yet, far from perfect, and some limitations are apparent. The key dimensions in both upper- and lower-body systems, for example, exert only limited control on waist circumference. It was felt, however, that this problem lends itself to solution by clothing designers who can deal with adjustability at the waist much more easily than in the shoulder or hip areas.

Waist measurements, in general, are highly problematical when dealing with a mixed population of men and women. Often used as a key dimension in traditional sizing systems devised for a single sex, waist-related dimensions are unreliable as sizing indicators when the sexes are combined--

not only because available data reflects so many variations in waist-measuring techniques but because men and women themselves normally locate their waists in somewhat different areas of the torso.

As in the introduction of any new system, the use of unconventional key dimensions may pose problems to designers or procurement personnel accustomed to more familiar sizing dimensions such as bust/chest or waist measurements. Further, for the same reasons that traditional sizing dimensions will not work well to sort an integrated group of men and women into usable size categories, neither will tables of equivalency using traditional sizing dimensions in the place of the recommended sizing dimensions. This difficulty should be easily resolvable with patience and the willingness to adapt to new approaches.

Other problems, as yet unforeseen, may also arise in the practical application of the recommended sizing programs. While the sizing data assembled as a result of the research described in this report is the best available and clearly shows promise of good results, no sizing system can be adjudged wholly successful until fully validated by fabrication of the garments and comprehensive anthropometric fit-testing.

It is our recommendation that such an evaluation be conducted before any large-scale production of garments based on the recommended sizing programs takes place.

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APPENDIX A

PROCEDURES FOR COMPUTING SIZE VALUES

Statistics to describe each size in each program were computed with the help of regression equations. The regression equations used were of the form, $Z = Ax + By + C$, where Z is the predicted dimension and x and y are the key sizing dimensions. If, for example, sleeve inseam were to be predicted from a given shoulder circumference and stature, then the equation would appear as follows:

Sleeve Inseam = (A * Shoulder Circ) + (B * Stature) + C

The values A, B, and C are computed using means, standard deviations, and correlation coefficients between the three dimensions from a given sample; in this case, the 1977 Army women's sample or the 1966 Army men's sample. The equations are always specific to the sample from which they are derived. After computing the A, B, and C values for the 1977 Army women, the above equation appears as follows:

Sleeve Inseam = (-0.0016 * Shoulder Circ) + (0.2994 * Stature)
+ (-1.411 in.)

This equation can then be used to predict sleeve inseam at any level of shoulder circumference and stature for U.S. Army women. "Mid-size" values used in this report were derived from such equations for each dimension from the midpoint of the key dimension categories. They represent the most likely value for a person at the midpoint of the size category.

To compute the mid-size value for sleeve inseam in size Medium Regular (see Table 9, page 47), for example, the midpoint shoulder circumference and stature values are used as predictors in the above equation. The range for shoulder circumference in that size is from 41.0 to 43.99 inches, so the shoulder circumference midpoint is approximately 42.5 inches. The range for stature in that size is from 66.0 to 69.99 inches, so the stature midpoint is approximately 68.0 inches. Inserting these values as predictors into the equation gives:

Sleeve Inseam = (-0.0016 * 42.5 in.) + (0.2994 * 68.0 in.)
+ (-1.411 in.) = 18.8802 in.

This value rounds to 18.88 inches which is the mid-size value found on that table.

Regression equations are accompanied by an error term referred to as the standard error of estimate (SE EST), which is computed from the standard deviations and correlation coefficients. This term identifies the amount of variation in size to be expected about the most likely value. It functions much like the standard error of the mean for the total sample. The SE EST for the above equation is equal to 0.686 inches.

To create the size standard deviation (SZ-SD) which accompanies the mid-size value on the sizing tables, the SE EST was employed. The formula for computing the SZ-SD is as follows:

$$SZ\ SD_{(z)} = \sqrt{SD\ EST^2 + \frac{(A * SIZE\ WIDTH_{(x)})^2}{12} + \frac{(B * SIZE\ WIDTH_{(y)})^2}{12}}$$

where A and B are the same as in the regression equation, size widths x and y are the size category interval widths for the key dimensions, and 1/12 is Sheppard's correction for grouping.

Since the sample used provides the necessary components to compute the SE EST, A, and B, the only actual variables left, are the size widths.

For the upper body program, again, all the size category widths are the same--the width for shoulder circumference is three inches and the width for stature is four inches. Therefore, the SZ-SD for all the sizes will be the same for each sex. Plugging these values into the above equation gives:

$$SZ\ SD_{(z)} = \sqrt{(0.686)^2 + \frac{(-0.0016 * 3.0\ in.)^2}{12} + \frac{(0.2994 * 4.0\ in.)^2}{12}}$$

$$= 0.76819\ in.$$

This value rounds to 0.77 which is the value to be found in the sizing tables for this program.

Once the mid-size value and the SZ-SD were computed for each dimension, these statistics were employed to create the range-to-be-accommodated values. These values represent approximately the 5th to 95th percentile values for each sex within a size and are the mid-size values plus or minus 1.67 SZ-SD. The SZ-SD functions in the same way as the total sample standard deviation.

The last column of values found on the sizing tables contains recommended design values. These values are predicted in the same way as the mid-size values except that they were computed from the largest key dimension sizes in the category. Thus, for size Medium Regular in the upper body program, 43.99 and 69.99 inches were used as input for shoulder circumference and stature, respectively. In the case of sleeve inseam, the male regression equation was used with these values as input for this size. To predict the hip breadth recommended value, these values were used as input into the female equation. The sample (male or female) used to predict recommended values was selected so that the resulting values would be additive, as well as large enough to accommodate most persons of either sex within the size.

APPENDIX B

MEASUREMENT DESCRIPTIONS

WEIGHT

Women: the weight of the subject wearing underwear.

Men: same.

HEIGHTS AND LENGTHS

CALF HEIGHT

Women: the vertical distance from floor to the level of the maximum circumference of the calf.

Men: same.

CROTCH HEIGHT

Women: the vertical distance from floor to mid-point of crotch.

Men: same.

KNEECAP HEIGHT

Women: the vertical distance from floor to the top of the kneecap (patella).

Men: same.

SHOULDER HEIGHT

Women: the vertical distance from floor to acromion, the lateral edge of the acromial process of the scapula.

Men: same.

SHOULDER TO ELBOW

Women: the distance along the long axis of the upper arm from acromion to the inferior tip of the olecranon process of the elbow.

Men: same.

HEIGHTS AND LENGTHS (cont'd)

SLEEVE INSEAM

Women: the distance from the front edge of the armpit to the little finger side of the wrist measured with the arm held slightly away from the body, palm forward and the tape tense.

Men: same.

STATURE

Women: the vertical distance from floor to the top of the head.

Men: same.

WAIST BACK

Women: the surface distance from the "natural" waist to the seventh cervical vertebra (approximately at the base of the neck).

Men: the surface distance from the waist (at the level of the navel) to the seventh cervical vertebra (approximately at the base of the neck).

WAIST HEIGHT

Women: the vertical distance from the floor to the "natural" waist level.

Men: the vertical distance from the floor to the upper edge of the right hip bone.

ARCS AND BREADTHS

CHEST BREADTH

Women: the left to right breadth of the torso at the level of the bustpoints.

Men: the left to right breadth of the torso at the level of the nipples (thelion).

HIP BREADTH

Women: the maximum horizontal breadth of the hips.

Men: same.

ARCS AND BREADTHS (cont'd)

INTERSCYE BACK

Women: the surface distance across the back between points located midway between the upper ends of the armpit creases and the tips of the shoulders (acromion).

Men: the surface distance across the back between the upper ends of the armpit creases.

SHOULDER BREADTH

Women: the horizontal distance across the maximum protrusion of the right and left deltoid muscles.

Men: same.

SHOULDER LENGTH

Women: the surface distance from the neck-shoulder junction on the side of the neck to the tip of the shoulder.

Men: same.

CIRCUMFERENCES

ANKLE CIRCUMFERENCE

Women: the minimum circumference of the ankle.

Men: same.

ARM CIRCUMFERENCE AT SCYE

Women: the circumference of the scye (armhole) measured with the tape passing through the armpit and over the tip of the shoulder.

Men: same.

BICEPS CIRCUMFERENCE FLEXED

Women: the circumference of the arm at the level of the maximum protrusion of the biceps, measured with the elbow flexed 90°, the upper arm horizontal and the fist tightly clenched.

Men: same.

CIRCUMFERENCES (cont'd)

CALF CIRCUMFERENCE

Women: the maximum circumference of the calf.

Men: same.

BUST/CHEST CIRCUMFERENCE

Women: the horizontal circumference of the trunk, measured with the tape passing over the bra points.

Men: the horizontal circumference of the trunk, measured with the tape passing over the nipples.

HIP CIRCUMFERENCE

Women: the maximum circumference of the hips at the level of the maximum posterior protrusion of the buttocks.

Men: same.

NECK CIRCUMFERENCE

Women: the circumference of the base of the neck; this circumference is not in a plane perpendicular to the axis of the neck.

Men: the circumference of the neck measured just below the "Adam's Apple"; this circumference is measured on a plane slightly higher and closer to the perpendicular with regard to the neck axis than is the corresponding women's measurement.

SHOULDER CIRCUMFERENCE

Women: the horizontal circumference of the shoulders at the level of the greatest lateral protrusion of the deltoid muscles.

Men: same.

UPPER THIGH CIRCUMFERENCE

Women: the circumference of the leg measured at the level of the lowest point of the gluteal furrow (point at which the buttock meets the thigh).

Men: same.

CIRCUMFERENCES (cont'd)

VERTICAL TRUNK CIRCUMFERENCE

Women: the circumference of the torso measured with the tape passing through the crotch, over the protrusion of the buttock, the midshoulder point and the tip of the bra. The tape follows the contour of the body's back but not its front below the bustpoint.

Men: measured the same except that the tape generally follows the contours of the body's front and back.

WAIST CIRCUMFERENCE

Women: the horizontal circumference of the waist at "natural" waist level.

Men: the maximum horizontal circumference of the waist measured at the level of the navel.

WRIST CIRCUMFERENCE

Women: the circumference of the wrist at stylion (wrist bone on the thumb side of the hand).

Men: same.